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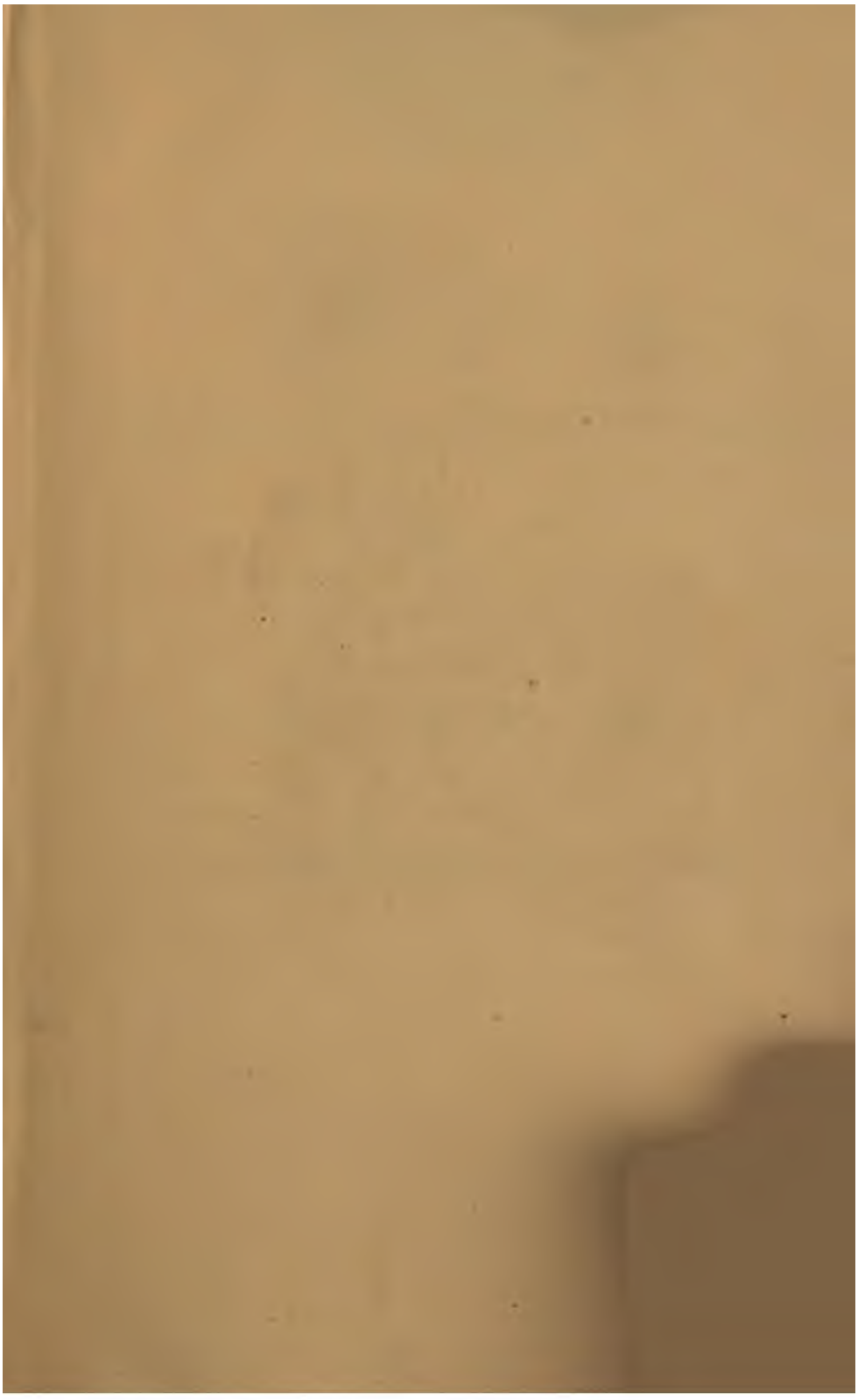

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PARIS: J. B. BAILLIERE, RUE HAUTEFEUILLE.
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1851.

CHEMICAL TECHNOLOGY;

OR,

CHEMISTRY,

APPLIED TO THE ARTS AND TO MANUFACTURES.

BY DR. F. KNAPP,

PROFESSOR AT THE UNIVERSITY OF GIESSEN,

DR. EDMUND RONALDS,

PROFESSOR OF CHEMISTRY AT QUEEN'S COLLEGE, GALWAY,

AND

DR. THOMAS RICHARDSON,

OF NEWCASTLE-ON-TYNE.

ILLUSTRATED WITH NINE ENGRAVINGS, AND ONE HUNDRED AND TWENTY-NINE WOOD-CUTS.

JOHN HEWSTON JR

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PREFACE

The researches of modern chemists in the organic department of the Science, and the rapid progress that has been made in consequence of the more perfect methods of analysing organic bodies have thrown an entirely new interest over the subjects discussed in this volume. The numerous accurate analyses which we possess of the various substances employed as food, and of the juices and tissues of animals consuming them, have opened up a field of inquiry respecting the function which each is destined to perform in the animal economy, the results of which must prove of the utmost importance to the Science of Physiology, as well as to Practical Dietetics and Medicine.

Our aim has been, however, in unison with the scope of our whole undertaking, to confine our attention as strictly as possible to the chemical principles and operations concerned in the manufacture of the actual food from the raw material.

Since printing the section which is devoted to the discussion of the quality of water, and the methods of purifying it for domestic use and manufacturing purposes, a large body of evidence has been collected by the Board of Health Commission, with reference more particularly to the best method of affording an abundant supply of wholesome water to the metropolis. Our account of the subject will, however, be found to contain every material point, for which we are indebted to our friend, Professor Clark, one of the principal witnesses examined before the Board.

For the account of the manufacture of tea in China, we are under great obligations to the labours of Mr. Ball, whose admirable work upon that subject has supplied us with numerous illustrations.

In preparing the present volume for the press, one of our great difficulties has been to breast our subject—the rapidity with which one improvement succeeds another, leaves the former articles in arrear of the actual condition of those subjects to which they are devoted. While this is a just subject of congratulation to every one interested in the progress of society in their material well-

being, it is the more tantalizing to us as author and editor to find our work overtaken by the ceaseless current of discovery, and its application to the arts of life, and of which progress we cannot enable our reader to form a better conception than by the statement that upwards of one thousand pages of new facts and reasoning in the Science of Chemistry and its application, are published monthly.

A survey of this intense mental activity, and its general tendency towards practical application in the daily business of life, ought to lend great encouragement to those interested in such branches of trade as are suffering from changes in fiscal arrangements, or other temporary causes beyond their present control. In none is this consideration more strikingly applicable than in the growth and manufacture of colonial sugar, and the contrast it presents to the present state of the beetroot-sugar. Ignorant as we are of many of the minor practical details, it is impossible for us as Chemists not to be forcibly struck with the many instances in which the former might not profitably draw upon the resources of the latter, not so much in the appropriation of the precise arrangements as in the adoption of many valuable ideas, to be modified according to the position of the planter.

Improvements in the manufacture of colonial sugar, processes by which a larger amount of juice can be extracted from the cane, and a less proportion of the sugar contained in the juice converted during the manufacturing processes into molasses and waste, become of the last importance to our colonial plantations. Particular attention has consequently been bestowed upon this section, and we owe our best acknowledgments to the very kind co-operation of Messrs. Pontifex and Wood, especially Mr. E. A. Pontifex, and of Mr. Bessemer, and trust that our present volume will afford a full account of all the most recent adaptations of machinery intended to effect those objects. It appears to us that there is no field upon which the intelligent and enterprizing capitalist could invest his skill and capital with better chance of success than in the introduction of improved machinery and processes into the West Indian sugar plantations.

SEPTEMBER, 1851.

TECHNOLOGY;

OR,

CHEMISTRY APPLIED TO THE ARTS

AND TO

MANUFACTURES.

GROUP V.

OR THOSE BRANCHES OF CHEMICAL INDUSTRY INCLUDING THE PRODUCTION OF FOOD AND RELATED TO AGRICULTURE.

INTRODUCTION.

GENERAL PRINCIPLES OF NUTRITION.

Food. — The simple substances (elements according to the present state of chemistry) of which the bodies of animals and of man are composed, are not peculiar to their organization, but are found in plants, and occur also in minerals, where there is no organized structure. Carbon, hydrogen, nitrogen and oxygen, phosphorus, sulphur and lime compose the larger proportion of the substance of the animal frame, the same ingredients enter into the composition of plants, and even of the earth itself in the numerous rocks which cover its surface. The science of physiology, which treats of the phenomena and laws of organic life, proves that those identical elements of which the animal frame is composed at any given period, are by no means those which *permanently* constitute the substance of its organs. In a very short time, as compared with the duration of life, the material which has served to sustain vital activity ceases to be applicable to that purpose, and is excreted and replaced simultaneously

by new matter in the form of food. The matter which is supplied must, as far as its chemical nature is concerned, replace that which is excreted in every individual element, if life is to be sustained, and the various functions of the body are to be kept in active operation.

The immediate consequence of this law, the incessant consumption and reproduction of the substance of the animal frame, demands a continuous supply of material from without. There is an imperative necessity for an assimilation of matter which is, chemically, equivalent in properties to that which passes away, and which can afterwards be elaborated by the organs for their own purposes. In a more extended scientific sense, all substances taken into the system come under the appellation *food.* They, however, differ as well with reference to their respective sources as in their properties and destination. Thus we have:

AIR, WATER, VEGETABLE AND ANIMAL FOODS.

Proximate constituents of food.—Although the material substance of organized beings, such as plants and animals, has been proved by chemical analysis to consist of the elements already named, it must not be supposed that the individual parts, such as blood, flesh, membrane, have been formed simply by bringing their several elements into contact: on the contrary, the vital power first produces from these elements, by the agency of chemical forces, peculiar, highly complex substances, and these then form the real building materials from which it constructs the various organs of the body. Compounds such as these latter, are called in chemistry *proximate constituents,* in contradistinction to the elementary bodies. Thus, for instance, calcium, sulphur, oxygen and hydrogen are the elementary constituents, lime, sulphuric acid and water the proximate constituents, of gypsum.

If the opposite method is pursued, as is the most natural in the chemical investigation of the organism, and one organ is separated anatomically from those surrounding it in order to undergo chemical decomposition, we first arrive at the proximate, and afterwards at the elementary, constituents of its composition. The study of vegetable and animal bodies by these two methods, and more particularly the comparison of the two, has led to the discovery of the most interesting and important relations, which

cannot be overlooked without creating a serious impediment to a thorough and clear conception of the nature of food in the more limited sense of the word, *i.e.* food of vegetable or animal origin.

The first fact which attracts attention, is the presence of nitrogen in some of the proximate constituents of the body, and its absence in others.

Non-nitrogenous alimentary substances.—This class—comprising the constituents which are devoid of nitrogen—is always composed of three elements, carbon, hydrogen and oxygen, and may be separated into three subdivisions. In the one, the two latter elements are found combined in the same proportions as in water, *i.e.* 1 equiv. to 1 equiv, for instance:

	Equivalents:		
	Carbon.	Hydrogen.	Oxygen.
Starch	12	10	10
Cane-sugar	20	11	11
Grape- or starch-sugar	12	14	14
Milk-sugar	12	12	12
Gum	12	11	11

In the second subdivision, the amount of oxygen, *i.e.* the number of equivalents of oxygen is larger than that of the hydrogen; this is the case with many acids of organic origin, for instance:

	Equivalents:		
	Carbon.	Hydrogen.	Oxygen.
Tartaric acid	4	4	5
Malic acid	4	2	4

In the third and last subdivision, the proportion of oxygen is much below the hydrogen and carbon, which preponderate. All the fats, the resins, wax, are included under this head, for instance: in 100 parts of

	Carbon.	Hydrogen.	Oxygen.
Pigs' lard	79.10	11.15	9.75
Mutton suet	79.00	11.70	9.30*

With the exception of water and fat, no other non-nitrogenous substance exists in the animal frame.

Among the nitrogenous proximate constituents of organized

* Compare Vol. I, p. 104.

beings, there are some which constantly occur and are present everywhere, and these consequently play a very important part; in other words, these are the constituents which the vital principle chiefly employs in the production of the different organs. They are found in plants and animals widely differing from each other, and in these again in the most different organs, so that they necessarily assume a very general importance. While our food, therefore, in the limited sense of the word, is composed of parts of plants and animals, these proximate constituents must also play a very conspicuous part in the process of nutrition.

Nitrogenous alimentary substances.—The nitrogenous proximate principles of plants are chiefly: *vegetable albumen, vegetable fibre, (fibrin), legumin* and *vegetable gelatin.* Possessing very different properties with reference to solubility in water, alcohol, &c., these substances present a remarkably similar deportment towards powerful reagents, such as hydrate of potash, hydrochloric acid, and others, all of which give rise to decomposition. It appears that the same products of decomposition are formed from any of these different substances, a fact which is indicative of great similarity in their elementary composition. They contain, in addition to carbon, hydrogen, nitrogen and oxygen, also sulphur, and some of them phosphorus. The quantities of the two latter ingredients contained in them, are subject to considerable variation, the first four being contained in equal proportions in all. The same has been found to hold good with the corresponding constituents of the animal body, inasmuch as they are nitrogenous. These are: *animal albumen* (from blood or eggs), *animal fibrin* (from blood or muscle), *casein* (from milk).

This will be evident from the following table:

	Carbon.	Hydrogen	Nitrogen.	Sulphur.	Phospho-rus.	Oxygen.
Vegetable albumen .	54.86	7.28	15.88	0.88	21.10	
Vegetable fibrin . .	54.03	7.23	15.74	—	23.00	—
Legumin	54.59	7.37	15.78	0.49	21.77	
Vegetable gelatin . .	54.96	7.17	15.80	0.72	0.0	21.35
Animal albumen . .	54.42	7.22	15.38	1.43	21.55	
Animal fibrin . . .	54.44	6.99	15.82	1.32	21.43	
Casein*	54.71	7.21	15.70	0.95	0.0	21.43

* See Milk.

These numbers are the mean results of numerous analyses extracted from the extensive researches which chemists have latterly instituted in this department. They clearly point out, that the proximate constituents of vegetables not only exhibit the correlation alluded to amongst themselves, but share it with those of the animal frame. Vegetable food, consequently, embraces substances which are closely related, as far as their chemical constitution is concerned, to the corresponding ingredients of animal food, and to those of the living organism itself; substances which must be considered as chemically elaborated, and highly prepared, so to speak, in order to be applied directly by the vital principle to the production of parts of the animal organism.

In other nitrogenous ingredients, the relations are different, and in some, are not so clearly developed. This is the case with the substance which forms the basis of hair, epidermis, nails, horn, &c.; also with the substance composing the gelatinous tissues and chondrin (membrane, sinew, cartilage, gelatin). These differ in composition to those mentioned in the table.

Little or nothing is known of the relation subsisting between the active nitrogenous principles of coffee, tea, spices, &c., and the process of nutrition.

It is to be anticipated that substances differing so widely in chemical properties as those which occur among the constituents of food—substances in which the relative proportions of their ingredients and the elements of which they are composed vary so considerably, some containing nitrogen, while others are free from it; some containing sulphur, others none; some an excess of carbon, others the reverse—must serve different purposes in the animal economy. What, then, are these different purposes? On this point, modern researches have thrown considerable light. Experiment has proved that any single alimentary substance, for instance, sugar, or starch alone, is incapable of supporting animal life. On the other hand we know, that wherever nature herself has prepared the food, as in the case of the mother's milk for her young, that food is always of a mixed nature, *i.e.* it embraces alimentary principles of very different composition. In milk, we find a nitrogenous substance, *casein*, containing sulphur; among the non-nitrogenous ingredients, *butter*, a body very rich in carbon, a less carbonaceous ingredient is the *milk-sugar*; and

besides these, there are salts composed of phosphoric acid, lime and chloride of sodium.

All the facts that have been elicited upon this subject indicate that some of the constituents of food are applied by the vital power to the reproduction of the different parts of the body, and are therefore peculiarly adapted to the reconstruction of the tissues, &c. These have been called *plastic aliments.* They must contain nitrogen — as is the case with albumen, fibrin, and casein — in order to form muscle, while phosphorus and lime are likewise necessary to their composition, to adapt them for the construction of bone. Other kinds of food take no part in the actual composition of the body—do not enter into its permanent substance at all, but are solely employed in the production of animal heat. The production of heat in the body is, however, dependent upon the contact of these substances with the inspired air, after they have been dissolved by the blood. A gradual chemical action occurs between the oxygen of the air and these substances, which effects their decomposition, with a simultaneous evolution of heat—a process similar to that of combustion, but very much slower. These respiratory aliments, or *"heat-producing" substances,* are only retained and applied to the actual construction of parts of the body, under circumstances depending upon the process of respiration, when they subserve for the production of fat.

It appears, therefore, from these remarks, that the term *nutritive,* has always a very limited signification in common parlance. Those kinds of food only can really be called nutritive, which afford material for the exercise of all the functions of the body at once. Milk is the true prototype of all food, and every aliment should at least contain representatives of each proximate constituent of milk. Thus nature has furnished a certain normal type of food, which cannot be neglected or overstepped with impunity, and which man's instinct points out to him in an extraordinary manner. One of the greatest evils of civilization, which so often compels man to depart from a natural mode of life, consists in his being led by wrong notions, or forced by want and poverty, to pay no attention to the voice of instinct, and to follow a course of living which does not admit of the full development of his bodily, and consequently of his intellectual powers,—in a word, which injures his health. Unfortunately, the evil conse

quences to health of an ill-regulated mode of life, generally show themselves but slowly, and are on that account not so easily traced to their true cause.

Food, properly constituted, should contain those substances which support the process of respiration, and those necessary for the restitution of the parts consumed in the transformation of the tissues, in such proportions as are required by these two functions. These objects are, however, very different under different circumstances, and vary with age, climate, mode of life, occupation, &c., so that they can only be ascertained in each case by instinct and experience. When an aliment is not thus normally constituted, when it contains relatively too much or too little of one of these constituents, the disproportion can be met by a change in the mode of life, or by an increased consumption. Men, for instance, who live solely upon animal diet, which is deficient in the necessary food for respiration, are obliged to take an excess of the other variety of food, which must be removed or worked off by an increased amount of bodily exercise, as exercise promotes the consumption of the tissues.

Value of food.—When the varieties of food produced in civilized countries by agriculture, and the breeding of cattle, are considered in a general point of view, it soon becomes obvious that a much larger proportion of the produce consists of the heat-giving aliments, than of the plastic. This, in ordinary life, has determined the signification of the term nutritive, and the price of food. Aliments containing a large proportion of the plastic ingredients are considered more nutritious, and are dearer than those which abound in the heat-giving principles. As the plastic ingredients are characterized by containing nitrogen, and as the amount of nitrogen in most of the substances of which these are composed only varies between 15 and 18 per cent, it has been with propriety assumed that the amount of nitrogen is a fair criterion of their respective nutritive powers. It must not, however, be overlooked, that this assumption is not mathematically correct, and that it presupposes a sufficient quantity of the heat-giving principle in every case. Upon this foundation, the nutritive value of the different kinds of food have been recently estimated according to their relative amounts of nitrogen. Thus we find :

IN THE FRESH STATE.

HORSFORD.	Percentage of nitrogen.	Equivalents or weights for an equal amount of nutritive power.	Percentage of water.	Practical equivalents.*
Talavera wheat from Hohenheim . .	2.59		15.43	
Whitington „ „ „ . .	2.68	100	13.93	100
Sandomier „ „ „ . .	2.69		15.48	
Wheaten flour from Vienna, No. 1. .	3.00		13.85	—
„ „ „ „ 2. .	2.12	90	13.65	—
„ „ „ „ 3. .	3.44		12.73	—
Rye (Staudenroggen) from Hohenheim.	2.78	101	13.94	97·6
Rye (Schilfroggen) . „ „ „	2.47		13.82	
Rye flour from Vienna, No. 1 . . .	1.87	141	13.78	—
„ „ „ „ 2 . . .	2.93	90	14.68	—
Jerusalem barley from Hohenheim. .	2.31	104	16.79	102
Common winter wheat „ „ .	2.79		13.80	
One-grained wheat (Triticum monococcum) from Giessen.	2.07	128	14.40	124
Kamtschatka oat from Hohenheim .	2.39	102	12.71	104
White early oat „ „ .	2.82		12.94	
Common rice „ „ .	1.16	228	15.14	225
Indian corn „ „ .	2.30	115	14.96	113
Tartar buckwheat „ „ .	1.56	170	14.19	166
Buckwheat flour from Vienna .	1.08	245	15.12	—
Garden pea „ „ „ .	4.42	59	13.43	59
Field pea from Giessen	4.57		19.50	
Garden bean from Vienna	4.47	58	13.41	57
White large bean from Giessen . .	4.59		15.80	
Lentiles from Vienna	4.77	55	13,01	55
White potato from Giessen . . .	1.56	192	74.95	581
Blue „ „ „ . . .	1.20		68.94	
Beet-root „ „ . . .	2.43	109	81.61	501
Carrots „ „ . . .	1.67		86.10	959
Mangel-wurzel „ „ . . .	1.81	154	82.25	689
Turnip „ „ . . .	1.45		83.28	919
Turnip-rooted cabbage, idem . . .	1.98		87.78	919
Onion, idem	1.18	224	93.78	1320

* Boussingault has endeavoured to establish the nutritive value of food by experiment, *i. e.* by practical observations and experiments in the feeding of cattle. His results are given in the fourth column of the table.

IN THE DRY STATE, AT 100° C. (212° F.)

	Percentage of nitrogen.	Equivalents or weights for an equal amount of nutritive power.	Percentage of water.	Practical equivalents.
THOMSON:				
White bread	2.27	100		
Black bread	2.63	86		
SCHLOSSBERGER:				
Agaricus deliciosus	4.6	49		
Cow's milk	3.78	60		
Cheese	5.27-7.11	43—31		
Yolk of egg	4.86	46		
White of egg	13.44	17		
Salmon, raw	12.35	18		
Salmon, boiled	9.70	23		
Oysters	5.25	43		
Eel, raw	6.91	25		
Eel, boiled	6.82			
Ham, raw	8.57	26		
Ham, boiled	12.84	17		
Herring	14.48	15		
Pigeon, raw	12.10	19		
Pigeon, boiled	12.33			
Mutton, raw	12.30	18		
Mutton, boiled	13.55	17		
Veal, raw	13.89	16		
Veal, boiled	14.50	15		
Beef, raw	14.00	16		
Beef, boiled	14.99	15		
Lamb, raw	13.26	17		

In these experiments the quantity of water contained in the fresh substances, was unfortunately not estimated, so that it is impossible to determine their relative nutritive values in the state in which they are consumed.

Two circumstances must not be overlooked in reference to these numerical values, which cause a difference between that theoretically found, and the actual or practical nutritive value. First, the constituents of the varieties of food are not in definite, fixed proportions; for instance, in the various species of corn, the amount of nitrogen in one and the same kind may vary several parts in the hundred, according to soil, manure, and season. Moreover, the nitrogenous ingredient can only serve as a measure of the nutritive power in as far as it is really digestible. Upon this latter point we are entirely deficient in accurate knowledge. It will be easily understood that the food we eat can only be nutritious as far as it is elaborated by the digestive organs, and actually taken up into the blood. Thus, the whole amount of produce given to horses and cattle as fodder, cannot be reckoned as actual nutritive food; for the seeds which birds pick out of the

excrement of these quadrupeds must obviously be deducted from the entire amount. In this manner an inferior food, capable of being thoroughly digested, may do more service than a richer food which partially resists digestion.

These explanations will serve to render more intelligible the technology of those branches of industry which are connected with the production of food.

I.—DESCRIPTION AND CHARACTERISTICS OF THE ARTICLES OF FOOD.

WATER.

Natural importance of water.—In the wide field of animate and inanimate nature, there are forces incessantly at work, amongst which the chemical are conspicuous; these together form a power which is, to a great extent, the cause of the phenomena and ceaseless changes that occur in our globe, and in all that covers it. It is an ancient chemical maxim, that chemical action is weak and of little energy when exerted between bodies in the solid state, but that it rises to its full intensity when one or more of these substances are in the fluid state. Solid bodies are, however, most easily rendered fluid by solution. When it is borne in mind that few bodies can resist the action of water, that nearly all are more or less soluble in that liquid, and when the fact is remembered that more than three-fourths of the surface of the earth is covered by water, and consequently a considerable portion of its mass is composed of water, which thus forms one of its geological components, we are led to the conclusion that the water on the earth plays the part of a general solvent, and is the agent employed to aid and assist the chemical and physical forces. Water is assisted in its functions by the constant change of state to which it is subjected. By evaporation, or the formation of gaseous water with the aid of heat, it is removed from the great reservoirs on the surface of the earth into the atmosphere, of which it then becomes a constituent part, and is wafted by the aërial currents in all directions, and consequently over the solid parts of the globe, where it is constantly being precipitated in some form or other. These deposits of water are caused by the cooling of the air itself containing the vapour (rain and snow), and also by its contact

with the surface of the earth, which has become cold either by the radiation of heat during the night (dew), or by the air being driven into colder regions. The condensed water then seeks, in accordance with hydrostatic laws, again to reach the great reservoir of the ocean, by penetrating into the porous mass of the earth's strata, and appearing again in less elevated parts in the form of springs, whence it collects into brooks, afterwards into rivers, and so at length reaches the sea. Water, from these causes, is found at all parts of the earth's surface, and that which evaporates and flows away is constantly replaced by these depositions. The whole upper layer of the earth, as far as we have been able to penetrate, is also saturated with water, and even in the greatests droughts of summer the surface never becomes absolutely, but only partially dried up, so as to be injurious to vegetation.

Water is thus extensively diffused in and about the earth itself, and, on the other hand, the amount of water in the bodies of living beings is very much more considerable than we are generally in the habit of supposing.

Three-fourths of the weight of the body of man and of the higher animals is composed of water; and the lower animals and plants are constituted in like manner. Even the wood of trees contains one-third, and more, of its weight of water. The animal frame, considered from this point of view, is no longer a solid mass, but an accumulation of vessels which are filled with liquid. The importance of water to the animal economy consists not only in its being an important ingredient of the body itself, but in its purveying to the system a number of other essential substances which it collects and retains during its passage into the form of springs and rivers. The extensive solvent power of water causes it to be laden with all those substances which it meets in the air and in the layers of earth through which it passes, in quantities proportionate to their degrees of solubility. These admixtures, when present in larger quantities than in ordinary drinking water, communicate medicinal properties to the water. But even in ordinary drinking water, these ingredients are so perceptible and so essential, that in an economic point of view they can by no means be treated as impurities. Their total or partial absence, as in distilled and rain water, render the water unsuitable as a beverage. These ingredients exercise, moreover, a very important influence in many of

the applications of water in the arts, and this fact renders a knowledge of them doubly interesting.

Chemical composition of water.—The aërial ingredients of water which separate from it in the form of bubbles when it is boiled or frozen, are, according to the state of the weather, equal to $\frac{1}{30}$th, often $\frac{1}{25}$th, or even $\frac{1}{20}$th of its entire volume, so that in 1 cubic foot of water there are 33½, 40 to 50 cubic inches of air. This air is a mixture of the same constituents as atmospheric air, but they are not present in the same proportions, the air contained in water being much richer in oxygen, and containing 32 per cent of its volume of that element. On an average, there are in 100 cubic feet of water:

	By volume:	By weight:
Oxygen . .	1280 cub. inch.	28.66 grammes — (442.62 grains).
Nitrogen . .	2643 to 2563 „ „	52.30 to 53.71 „ — (807.7—783.1 grns.)
Carbonic acid	80 to 163 „ „	2.47 to 2.96 „ — (38.15—45.55 „)

or about 1 lb. of air in 570 to 600 cubic feet of water. The air contained in water, and its superior richness in oxygen, is of especial importance to those animals which breathe through its medium, and is the cause why boiled (airless) water very often exerts a different chemical action as compared with fresh aërated water. The atmospheric ingredients in water are, under ordinary conditions, as constant as those of the atmosphere itself. The mineral ingredients, on the contrary, are very variable in quantity and of very different natures, as might be expected from the great multiplicity of substances composing the surface of our globe.

The absolute quantity of saline matter contained in spring water has been shown by Grange to be influenced in some cases (as in the Valley of the Isère) by the relative height of the locality, and increases from the tops of the mountains towards the valleys. The relative quantities of the different salts is variable; the soluble salts, particularly the chlorides, were found in this instance to diminish; while the insoluble, or difficultly soluble salts, gypsum and carbonate of lime, increased as the site of the spring was at a lower level. The nature of the soil likewise alters the relative quantities of the different salts. The chlorides preponderate in magnesian soils, and vary from 25 to 32 per cent, while in anthracitic soil they do not amount to more than 10 or 16 per cent, and in calcareous soil to only between 4 and 8 per

cent of the saline matter. The sulphates are found in nearly the same proportions in calcareous and anthracitic soils; in the former they vary from 24 to 31, and in the latter from 18 to 37 per cent. In the Nicomien they do not amount to more than 5 or 12 per cent of the dissolved saline matter. The carbonates vary from 36 to 47 per cent in granitic soils, from 48 to 71 in anthracitic, and from 83 to 88 per cent in chalk soils. Soda salts (chlorides and sulphates) preponderate in magnesian, and particularly in anthracitic soils; the total quantity of sulphates in the latter soils is much greater. Magnesian salts are remarkably constant in water from magnesian and anthracitic soils, their relative quantity averages between 19 and 23 per cent in water from granitic rocks and slates, and between 11 and 23 in anthracitic formations.

A general view of these will be obtained from the tables below:

IN 100,000 PARTS OF DRINKING WATER.

Source of the Water.	Carbonate of		Silica.	Sulphate of		Chloride of			Nitrate of lime.	Organic matters.	Total of the non-volatile ingredients.	Carbonic acid.	Name of the Analyst.
	Lime.	Magnesia.		Lime.	Magnesia.	Calcium.	Magnesium.	Sodium.					
Seine water above Paris	11.3	0.4	0.5	3.6	0.6	1.0	0.8	—	trace	trace	18.2	—	Bouchardat.
Water from the Marne	10.5	0.9	0.6	3.1	1.2	—	1.7	—	—	„	18.0	—	„
„ „ „ Ourcq, near St. Denis	17.5	2.0	2.0	15.3	7.0	—	4.0	trace	—	„	47.8	—	„
„ „ „ Jonne, near Avallon	4.3	—	1.9	trace	—	1·5	—	„	—	„	7.7	—	„
„ „ „ Beuvronne	25.7	—	—	20.3	—	8.5		—	—	—	54.5	—	Colin.
„ „ „ Therovenne	26 2	—	—	20	—	3.6		—	—	—	31.8	—	„
„ „ „ Gergogne	18.0	—	—	1.5	—	1.5		0 9	—	—	21.9	—	„
„ „ „ Bièvre	13.6	—	—	25.1	—	10.9		1.2	—	—	50.8	—	„
„ „ Arceuil	16 9	—	—	16 9	—	11.0		1.9	—	—	46.7	—	„
Spring de Roye, near Lyons	23.8	—	trace	1.4	—	—	—	1.2	trace	trace	26.4	—	Boussingault.
„ „ Fontaine	23.4	—	„	1.7	—	1.3	trace	0.2	—	„	26.6	—	Dupasquier.
Rhône water, near Lyons (in June)	10.0	—	„	0.6	trace	trace	„	trace	—	„	10.6	—	Boussingault.
„ „ „ „ (in January)	15.0	—	—	2.0	0.7	0.7			—	„	18.4	—	Dupasquier.
Spring in the Jardin des Plantes, near Lyons	27.0	—	—	25.2	—	16.8	1.6	12.6	7.6	„	90.8	—	„
Water of the Lake of Geneva	7.2	0.7	0.1	2.6	3.1	—	0.9	—	—	0.6	15.2	—	Fingry.
„ „ „ Arve (August)	5.2	0.4	0.1	3 2	2.9	—	0.7	—	—	0.3	12.8	—	„
„ „ „ „ (February)	8.3	1.2	0.2	6.5	6.2	—	1.5	—	—	0.4	24.3	—	„
„ „ „ Loire, Orleans	1.7	—	—	—	—	5.1		trace	—	—	6.8	—	Guindaut.
„ „ „ Elbe, near Dresden	—	—	—	—	—	—	—	—	—	—	30.0	—	Petzholdt.
„ „ „ Weiseritz (at its junction with the Elbe)	—	—	—	—	—	—	—	—	—	—	30.0	—	„
„ „ „ Lämmchenbrunnen, near Dresden	—	—	—	—	—	—	—	—	—	—	30.0		„
„ „ „ Qneckbrunnen	—	—	—	—	—	—	—	—	—	—	30.0	7 cub. ft.	„
„ „ „ Schlossbrunnen	—	—	—	—	—	—	—	—	—	—	30.0		„
„ „ „ Kreuzbrunnen	—	—	—	—	—	—	—	—	—	—	100.0		„
„ „ „ Hotel de Saxebrunnen	—	—	—	—	—	—	—	—	—	—	100.0	16 cub. ft.	„
„ „ „ Spring at the Salomonis-apotheke	—	—	—	—	—	—	—	—	—	—	130.0		„
				Sulphate of potash.	chloride of potassium.	bicarbonate of potash.							
„ „ „ Artesian well at Grenelle, Paris	6.8	1.42	0.5	1.20	1.09	2.96	—	—	—	0.24	—	—	Payen.

IN AN IMPERIAL GALLON (70,000 GRAINS), THE FOLLOWING QUANTITIES HAVE BEEN FOUND IN GRAINS.

	Carbonate of		Sulphate of				Phosph. of lime.	Chloride of			Silica.	Crenic acid.	Apocrenic acid.	Extractive matter.	Soluble organic matter.	Insoluble org. matter.	
	Lime.	Magnesia.	Magnesia.	Lime.	Potash.	Soda.		Magnesium.	Sodium.	Calcium.							
Thames at Twickenham	12.75946	1.02711	....	0.45073	0.66794	2.00011	trace	....	....	1.75021	0.27314	....	....	....	2.28536	1.19483	G. F. Clark.
„ at London bridge	8.1165	....	....	....	0.2695	3.1052	„	0.0798	2.3723	6.9741	0.1239	....	....	....	2.3380	4.6592	Ashley.
„ at Greenwich	14.3997	....	0.5475	....	1.3710	3.9224	„	1.1482	....	1.6272	0.7958	....	....	....	4.0810		Bennett.
Water supplied by Hampstead Water-works	3.83250	3.40830	....	4.42018	3.27812	4.81130	0.27672	....	17.75814	....	0.28589	0.16590	0.08403	1.71990	....	....	Mitchell.
Deep well-water at Combe and Delafield's	6.18	1.08	....	....	....	24.25	0.19	....	12.74	....	44	....	....	....	....	....	Graham.
	....	....	....	....	....	11.68 carb. of soda	phosph. of iron										
						0.24											
	3.255	2.254	....	....	13.671	8.7493	0.034041	....	20.0585	....	0.971	0.1372	0.0987	0.672	....	....	Abel & Rowney.
Well in Trafalgar Square	....	....	....	....	....	18.0488 carb. of soda											
						0.291 phosph. of soda.											
	3.50	1.50	....	....	....	13.14	....	....	10.53	....	0.50	traces of organic matter, iron, and phosphoric acid.		....	....	....	Brande.
Well at the Royal Mint	....	....	....	....	....	8.63 carb. of soda											
Whittle Dean for Newcastle-on-Tyne	6.735	.450	....	1.639	....	....	....	.228	.803	.946	.731	traces	....	....	....	....	Richardson.
River Eden, near Carlisle	4.51	trace	....	1.68	....	....	....	.86	trace.	0.61	.37	traces, also iron.		....	....	....	....
Hartlepool Tank	11.707	8.192	....	44.658	5.388	20.814	....	12.391	19.284	....	.501	traces.		....	....	....	....
Alnwick Well	.49	.88	....	.70	....	....	....	....	2.19	.55	.16	....	....	1.16	....	....	Browell.
					Carbonate of Potash.					Silica, phosphate of iron, sesquioxide of iron, carb. of magnesia.					Organic matter.		
River Lea, at Horn's Mill	12.54	....	....	....	1.45	....	....	....	0.48	....	....	1.33	....	....	3.20		
Woolmer spring, near Hertford	15.75	....	....	....	1.02	....	....	....	0.34	....	....	1.05	....	....	2.88		Campbell.
Mimram River, ditto	16.0	....	....	....	1.50	....	....	....	0.30	....	....	1.04	....	....	3.50		
Beane River, ditto	15.0	....	....	....	1.00	....	....	....	0.65	....	....	1.08	....	....	2.0		
Holt's Brewery, Ratcliffe	7.223	2.114	....	....	1.262	6.280	....	....	10.057	....	1.146	0.194 carb. of iron	....	....	0.574		Mitchell.
						6.499 as Carbonate.											
						14.324											
Spring Water, Wolverton.	10.96	2.319	....	....	....	6.576			6.003	....	0.20	0.540 phosph.	....	....	2.85		Giles.
						Carbonate.	Nitr.										
Water of Exe, at Exeter.	0.896	0.064	0.16	3.04	....	8.08	0.16	0.64	4.24	traces	alumina	of iron.	....	....	1.6		Herapath.

THE FOLLOWING QUANTITIES OF SOLID MATTER, IN GRAINS, IN AN IMPERIAL GALLON OF VARIOUS WATERS IN AND ABOUT LONDON, HAVE BEEN RECORDED BY MR. BRANDE.

Thames at Greenwich	27.9	Berkeley Square deep well	60.0
„ London	28.0	Tilbury Fort deep well	75.0
„ Westminster	24.4	Goding's Brewery, Lambeth, deep well	50.0
„ Brentford	19.2	Ditto ditto shallow well.	110.0
„ Twickenham	22.4	More's Brewery, Old Street, deep well	38.0
„ Teddington	17.4	Ditto ditto shallow well.	110.0
Average of the Thames between Teddington and Greenwich	23.2	Trafalgar Square Fountains' deep well	68.9
New River	19.2	Well in St. Paul's Churchyard	75.0
Colne	21.3	Well in Bream's Buildings	115.0
Lea	23.7	„ „ St. Giles', Holborn	105.0
Ravensborne, at Deptford	20.0	„ „ St. Martin's, Charing Cross	95.0
Combe and Delafield, Long Acre, deep well	56.8	„ „ Postern Row, Tower	88.0
Apothecaries' Hall, Blackfriars, deep well	45.0	Artesian well, at Grenelle, Paris.	9.86
Notting Hill deep well	60.6		
Royal Mint deep well	37.8		
Hampstead Water-works' deep well	40.0		

Ragsky has analysed the water from two Artesian springs in Vienna, the one (A) near the Mariahilf line, the other (B) in the court-yard of the Vienna and Raab railway. Under (C) we append an extract from Johnstrug's analyses of Copenhagen spring water. In the amount contained in 16 ounces of the water is given in Vienna grains, in (B and C) the quantity contained in 10,000 parts of the water.

	A.	B.	C.
Carbonate of lime	2.800	0.0078	2.68—5.13
„ „ magnesia	0.694	0.0043	0.19—0.61
„ „ soda	—	0.6387	—
„ „ protoxide of iron	0.010	0.0010	—
Chloride of potassium	—	—	0.51—7.21
„ „ sodium	—	0.2893	
„ „ calcium	0.099	—	—
„ „ magnesium	1.553	—	0.26—0.75
Sulphate of potash	—	—	0. —0.75
„ „ lime	1.979	—	0.09—0.88
„ „ magnesia	—	—	0. —0.75
Nitrate of soda with some potash.	0.977	—	—
„ „ magnesia	1.155	—	—
Phosphate of lime	—	—	0.07—0.39
Silica	0.132	0.0122	0.18—0.31
Loss and organic substances	0.146	0.0237	—
Volatile compounds	—	—	0. —0.60
Free carbonic acid	2.180	—	—

Boutron-Charlard and O'Henry have examined the composition of the water supplying the public fountains of Paris, with the following results: water of the Seine, taken at Pont d'Ivry (A), at Pont Notre Dame (B), at the pump du Gros-Caillon (C), and at the pump de Chaillot (D), the water of the Marne (E), and the water brought from Arcueil (F), the water of the Artesian well at Grenelle (G), and the water of the Canal de l'Ourcq (H). The following table indicates the number of grammes and the number of liters of gas contained in 1 liter of the water.

	A.	B.	C.	D.	E.	F.	G.	H.
Bicarb. of lime	0.132	0.174	0.229	0.230	0.301	0.158	0.0292	0.158
„ „ magnesia	0.060	0.062	0.075	0.076	0.120	0.060	0.0092	0.075
„ „ potash	—	—	—	—	—	trace	0.0100	—
Sulphate of lime	0.020	0.039	0.040	0.040	0.022	0.138	—	0.080
„ „ magnesia	0.010	0.017	0.027	0.030	0.018	0.072	—	0.095
„ „ soda							0.0320	
„ „ potash	—	—	—	—	—	—		—
Chlor. of calcium								—
„ „ magnesium	0.010	0.025	0.032	0.032	0.020	0.081	—	0.113
„ „ sodium							0.0570	—
„ „ potassium	—	—	—	—	—	—		—
Salts of potash	trace	trace	trace	trace	—	—	—	—
Alkaline nitrates	trace	trace	trace	trace	trace	trace	—	trace
Silica							0.0100	
Alumina	0.008	0.014	0.023	0.024	0·030	0.018	0.0020	0.069
Oxide of iron								
Organic matter	trace	trace	trace	trace	trace	trace	trace	trace
Total amount of solid matter	0.240	0.331	0.426	0.432	0.511	0.527	0.1494	0.590
Atmospheric air	0.003	0.003	0.004	0.003	trace	0.004	—	—
Free carbonic acid	0.013	0.014	0.014	0.013	0.013	0.070	—	—

The following waters were analysed by Deville:

(A) The Garonne at Toulouse.
(B) The Seine of Bercy.
(C) The Rhine at Strasburg.
(D) The Loire at Orleans.
(E) The Rhone at Geneva.
(F) The Doubs at Rivotte.
(G) The spring water of Mouillère.
(H) „ „ „ „ Bellecul.
(I) „ „ „ „ Arcier.
(K) „ „ „ „ Brégille, near Besançon.
(L) „ „ „ „ Suzon, near Dijon.
(M) „ „ „ „ Arcueil, near Paris.

(N) The spring in the Grande Rue of Besançon.
(O) „ „ „ Rue de la Préfecture of Besançon.
(P) „ „ „ Faculty of Sciences „ „
(Q) Water of the Isère, near Grenoble.

	A.	B.	C.	D.	E.	F.	G.	H.	I.	K.	L.	M.	N.	O.	P.	Q.
Silica	401	244	488	406	238	159	250	246	390	348	152	306	314	297	551	37
Alumina	—	5	25	71	39	21	43	43	90	65	10	53	94	62	39	35
Oxide of iron	31	25	58	55	—	30	—	—	—	—	—	—	—	—	—	—
Carbonate of lime	645	1655	1356	481	789	1910	2573	2561	2139	2079	2300	1990	2156	2017	2331	1037
„ magnesia	34	27	50	61	49	23	—	46	78	43	38	82	85	207	76	25
„ protoxide of manganese	30	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sulphate of lime	—	269	147	—	466	—	51	100	—	74	—	1638	802	663	2660	208
„ magnesia	—	—	—	—	63	—	—	—	—	—	—	—	—	—	—	302
Chloride of calcium	—	—	—	—	—	—	7	71	—	11	—	—	—	238	199	—
„ magnesium	—	—	—	—	—	5	20	40	—	27	—	166	72	255	615	7
„ sodium	32	123	20	48	17	23	—	—	20	—	32	376	556	15	—	36
Sesquicarbonate of soda	65	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carbonate of soda	—	—	—	146	—	—	—	—	69	—	21	—	—	—	—	—
Sulphate of soda	53	—	135	34	74	51	—	—	45	—	27	54	—	—	—	90
„ potash	76	50	—	—	—	—	—	—	—	—	—	201	57	—	—	
Nitrate of potash	—	—	38	—	40	41	23	44	trace	23	27	—	899	786	535	—
„ soda	—	94	—	—	45	39	118	156	—	48	—	570	304	870	1229	—
„ magnesia	—	52	—	—	—	—	—	—	—	—	—	—	—	—	—	—
„ lime	—	—	—	—	—	—	—	—	—	81	—	—	—	—	381	—
Silicate of potash	—	—	—	44	—	—	—	—	—	—	—	—	—	—	—	—
Entire solid matter	1367	2544	2317	1346	1820	2302	3085	3307	2831	2799	2607	5436	5340	5410	8616	1876
Free carbonic acid	170	162	76	18	79	178	390	267	208	226	237	256	202	263	350	110
„ nitrogen	79	120	159	202	184	182	154	101	153	142	167	127	171	157	202	30
„ oxygen	157	39	74		84	95	64	49	59	72	75	50	43	41	44	

The composition of water from several springs at Hartford, in Connecticut, is thus stated by Bull.

IN 10,000 PARTS OF WATER.

	I.	II.	III.	IV.	V.
Sulphate of lime . .	0.69	0.61	0.30	0.79	0.89
Chloride of magnesium	0.41	0.23	0.22	0.81	0.41
„ „ calcium .	1.12	0.70	0.39	—	1.79
„ „ sodium . .	1.91	—	—	—	2.67
Carbonate of lime . .	2.25	1.31	0.21	1.48	—
„ „ magnesia	0.19	—	—	—	1.51
Crenate of magnesia .	—	0.13	0.76	0.44	—
Carbonate of soda, equivalent for apocrenate	0.22	1.09	1.19	2.35	2.67
Oxide of iron . . .	0.04	0.38	—	0.04	trace
Alumina			0.14		
Lime	—	—	—	0.23	—
Silica	0.18	0.60	0.14	0.04	0.10
Loss	0.10	0.46	—	0.18	1.78
Total fixed ingredients	7.11	5.51	3.35	6.36	11.82

Incrustation.—From these and numerous other researches, it is clearly proved that the mineral constituents of drinking water consist chiefly of the carbonates, sulphates and chlorides of several bases; amongst the bases, lime often preponderates, while the alkalies are less frequently abundant. The carbonates of the earths are only held in solution by free carbonic acid, or in the state of bicarbonates, and are precipitated when the water is boiled, and this gas driven off. Sulphate of lime does not require the aid of carbonic acid for solution, but is precipitated in consequence of evaporation and its limited solubility in boiling water. It is a well known property of these earthy deposits, that they attach themselves to the sides of the vessels in which the water is boiled, in the form of a solid hard incrustation. Even for domestic purposes this incrustation is very inconvenient, as it cannot be removed in cleaning (at least from narrow-mouthed vessels), and every time the vessels are used, a fresh layer is deposited, which adds to the thickness of the former crust. In boilers, this circumstance is doubly inconvenient, firstly, because the tendency towards the formation of this deposit is much facilitated by the evaporation;

and secondly, because its injurious effects are much more extensive and dangerous. In a steam boiler, from one period of cleansing to the next, the total amount of the fixed mineral ingredients contained in the quantity of water supplied to it remains, while the pure water and the gases are alone evolved. A double-acting (expanding and condensing) Watt's engine, having 30 inches diameter in the cylinder, a piston velocity of 200 lines per minute, and a pressure of 15 lbs. on the square inch of boiler surface, requires 42 lbs. of steam per minute to exert its full power. Three thousand lbs. of water must consequently be evaporated from the boiler in 24 hours. Suppose the boiler to be fed with water like that from the Ourcq, (*v.* Table), the 3000 lbs. of water would leave in that time 1.43 lbs. of residue, a portion of which would be mechanically expelled with the steam, leaving, however, far the greater proportion to settle down as an incrustation, which very soon becomes burnt in. In a short time, the wrought iron of the boiler will not communicate the heat it receives from the fire directly to the water in its interior, but to the badly conducting solid incrustation, and the water will consequently be less quickly heated. It readily happens, under these circumstances, that a portion of iron, notwithstanding the boiler is well supplied with water, becomes red-hot, and should a part of the incrustation become detached, the water would come into sudden contact with the red-hot iron, giving rise to the instantaneous formation of an excessive amount of steam, and an explosion is the inevitable consequence. In steam-boats, where river water, containing, in addition to the salts in solution, a large quantity of suspended solid matter, or salt water from the sea, is employed for feeding the boiler, the evil is very much increased.

Methods of preventing incrustation.—Besides the frequent drawing off of the impure residual water from the boiler by means of sludge cocks, numerous other means have been advocated—not for precipitating the earthy matters, which would be impossible* —but to prevent their deposition as a solid crust on the inner surface of the boiler. Most of these methods consist in preventing the deposit from settling on the bottom, or in causing it to remain suspended in the water. Potatoes, the refuse from malt (grains) or from tan, all of which produce a viscous liquid when boiled in water, are employed for this purpose. Clay,† which

* Except upon the principle proposed by Dr. Clark, and described further on.

† The French Academy accorded the Monthyon prize to the discoverer of this remedy.

never settles in agitated water, charcoal powder (Ferrari), sawdust of mahogany (Roard), act in a different manner, but with the same result.* In an experiment with a boiler (of 20-horse power) consisting of two cylinders, 20 liters (rather more than ½ bushel) of sawdust was used, and after working incessantly for three months, no incrustation was formed, but only a muddy deposit, which was easily removed. The probable mode of action of these remedies consists in the earthy particles attaching themselves to the fragments of wood or charcoal instead of to the sides of the boiler, they thus remain suspended, and are prevented adhering to the bottom. The formation of the crust is a crystallizing process, and as crystals attach themselves much more readily to solid points than to flat surfaces, the angular particles of charcoal or wood afford points of attachment, which are *movable*, but much more calculated, from their roughness, to attract the crystals than the smooth sides of the boiler. Iron filings and powdered glass have also been tried, but not with the same success, in consequence of their inability to float.

Kuhlmann has observed, that when the lime and earthy ingredients in water are precipitated by alkalies, a much softer and perfectly amorphous deposit is produced, which does not cake together. The practice of adding from 100 to 150 grammes of soda (about 3½ to 5 oz.) for every horse power to the boiler is founded upon this observation. The soda has this advantage over clay, that it does not increase the amount of the deposit, or augment the evil by causing particles of mud to be forcibly carried into the internal parts of the machine, and thus interfering with its effective working. It also possesses the property of decomposing an unlimited quantity of carbonate (not sulphate) of lime, by combining immediately, after each addition of water, with the excess of carbonic acid, that holds the carbonate of lime in solution, and producing with it bicarbonate of soda, the excess of carbonic acid being again evolved from it in the course of boiling: it is thus enabled to exert the same action upon a fresh quantity of water.†

Muriate of ammonia has also been used to prevent incrustation. It is decomposed with carbonate of lime into carbonate of

* In the chalk districts of this country it is usual to place an oyster-shell in kettles, to prevent this deposit.

† This carbonate of soda, by rendering the water alkaline, is apt to produce priming, an effect which follows where the deep waters of London are used, which contain much carbonate of potash.

ammonia, which evaporates slowly with the water, and chloride of calcium, an exceedingly soluble salt, which does not settle or form an incrustation.

Boiler-incrustations are produced much more rapidly in boilers that are not constantly worked, than in those which are employed night and day.

A strict examination of all the circumstances connected with steam-boiler explosions has led to the conclusion that the organic matters contained in water may, amongst others, be one cause. These matters collect with the mineral substances, and form part of the incrustations, and when from neglect an insufficient supply of water is admitted to the boiler, and parts of it are exposed and become red-hot, the dry distillation of these matters may give rise to explosive mixtures of gas.

The nitrates are less often contained in water, and are, indeed, only exceptional ingredients; their source is partly from the rain in stormy weather, which contains small quantities of nitric acid, but more especially the drainings from sewers, cesspools, &c., which find their way into the springs and rivers about towns.*

It has been already remarked, that the earthy matter contained in water is essential to it as a beverage. Boussingault has endeavoured to prove in a very ingenious manner, that at least in young growing animals a great part of the lime, required for the formation of bone, is derived from the water which they drink. He states that a young pig, on his estate, assimilated in three months ½ of a pound of lime from the water given it, and that the spring from which the animals on the estate were supplied, afforded them yearly 2000 lbs. of lime, magnesia, and common salt.†

Supply of drinking water for domestic purposes.—It cannot be doubted, that a plentiful supply of drinking water, of such a character as is required by the wants of the system, containing,

* Dr. Clark is of opinion that a small quantity of nitrate in the water ought not to be assumed as prejudicial, but may be taken as proof that all organic matter has been oxidized.

† This appears a very remarkable and certainly an exceptional case. Taking 8 grains of lime, which correspond to 14.3 grains of chalk, as the average quantity contained in a gallon of water in London, a pig must consume 321 gallons of water in three months, or 3.5 gallons of water per diem, in order to obtain the stated amount of lime, a quantity altogether preposterous; pigs, however, thrive as well in London as elsewhere; and in Aberdeen, where the water contains not more than 1½ grains of chalk per gallon, if lime had to be supplied by the water in this proportion, the animal would be obliged to consume 30 gallons of water per diem.

therefore, the necessary mineral as well as aërial constituents, is one of the most essential objects for the preservation of public health. In forming new settlements, the presence of good water is decisive as to the choice of position, and most habitations, even from the earliest periods, have been fixed in the neighbourhood of springs. In small towns, the supply of water is generally easily obtained. In larger places, or extensive capitals, on the other hand, where the population has greatly increased, and the original supply from springs is totally inadequate to meet the wants of the people, or where, as in London and Paris, the geological character of the locality is not adapted to the natural formation of springs, the supply of water becomes a costly, and sometimes difficult problem for the officers of public health. Water, in these towns, must be paid for with money, while in smaller places it can be had for nothing, or for the time and labour of collecting. An abundant supply of water is not only essential to public health, as one of the most indispensable aliments, but also as the only means of insuring attention to cleanliness. Its immense importance to the public welfare and morality, the direct and powerful influence it exerts towards the improvement of the state of the less wealthy classes of the population, has been elicited in a striking manner by the Report of the Health of Towns' Commission to the House of Commons.*

An idea of the price of water, for the purposes here indicated, may be formed from the following actual cost for household purposes during the year:

	Shillings.
Newcastle-on-Tyne (exclusive of water-closets and stabling)	18 to 30
Sunderland	10 „ 30
Gateshead	10 „ 30
North-Shields . . .	18 „ 30
South-Shields . . .	10 „ 30

In the town of Bath, out of eight thousand houses, three thousand are supplied by the authorities of the town itself, for which they receive £3000 annually. Ten shillings are paid yearly for a daily supply of 40 gallons.

The average price now charged by the London companies for

* Second Report of the Health of Towns' Commission, 1845. See also Report of the General Board of Health on the Supply of Water to the Metropolis, 1850.

about 20 gallons per head of water, is 30 shillings per house, containing 7½ persons, or about 4 shillings per head, and no doubt it may be furnished at a lower price, since it is proposed by some capitalists to reduce that price to 20 shillings, or 2 shillings and 8 pence per head. Threepence per 1000 gallons is estimated as the maximum price to large consumers.

It may be interesting at the present moment, when the supply of water to the public is creating so much sensation in the country generally to describe the very successful method adopted for supplying Newcastle-on-Tyne with an abundance of good water, amounting to 1½ millions of gallons daily. The drainage water from a surface of 3540 acres, in a district where the average fall of rain is 36.92 inches per annum, ⅓ of which is estimated to run into the rivers of the district, is collected by a stream called Whittle Burn, and conveyed into five large reservoirs, capable of storing 218 millions of gallons; four of these reservoirs are destined to allow the water to deposit any matters that may be suspended in it, while the fifth and lowest, answers as a service reservoir, whence the supply is drawn. The water is conveyed from the reservoirs to the towns of Newcastle and Gateshead by metal piping, 2 feet in diameter and 12¾ miles in length. The service reservoir is 360 feet above the level of the river Tyne, at Newcastle, the two-foot main on entering that town is divided, and branches off into a number of smaller sized mains, one of which terminates with an open end in a small reservoir, 230 feet above the level of the river. Into this reservoir the surplus water flows, if the supply exceeds the demand; and again, it supplies the deficiency at times when the draught of the towns exceeds the quantity flowing through the supply pipe from the reservoir. This small reservoir, therefore, while acting as a store to equalise the supply and demand, is likewise performing the duties of a safety-valve, by fixing the maximum pressure throughout the town, at the amount due to its own elevation, instead of requiring the piping of the town to sustain the additional pressure of 130 feet, due to the height of the service reservoir. The water thus flows by its own gravity constantly to Newcastle, and supplies the town without the aid of machinery. The two-foot main would convey four times the present consumption, or 6 millions of gallons daily.

Impurity of water.—In some places, and in large towns where no pure water can be obtained, or only in insufficient quantity, and where any that is accessible must be employed, as in London

the water of the Thames, and in Paris that of the Seine, two systems are followed. The water is either supplied as it is found, and all purification is left to the consumers, or it is purified on a large scale before distribution.

While spring water in its natural state is perfectly clear, but impregnated by dissolved mineral substances, river water contains less saline matter in solution—the rivers being fed not only by springs, but likewise directly by rain water, which has not had the opportunity or time to take up any ingredients from the soil—but is much less free from suspended matters, these not having been separated mechanically by filtration through the porous earth. All river water contains very fine earthy particles, which communicate a certain degree of turbidity, and a peculiar colour (yellowish, or reddish) to it, due, however, in some localities to the peat-bogs which supply a large proportion of the river water in those cases. These substances require a very long time to deposit, even in still water, and a much longer time in flowing water. After rain, or thaw, and generally speaking, when the water is high, the amount of suspended earthy matter in river water is very much more considerable than after dry weather, and at low-water mark. In the water of the Seine it amounts to $\frac{1}{2000}$, so that a Parisian who drinks daily 2 pints, will have taken more than 6 oz. of earthy matter into his stomach in the course of the year. These muddy particles, chiefly of an argillaceous character, are by no means the only impurities in the water, for, in the neighbourhood of large towns particularly, it is often attended with a disagreeable taste and sometimes smell, arising from organic matter in a more or less advanced stage of decomposition, which it has taken up.

Filtration and disinfection.—The purification of water has generally the twofold object of clarifying it by straining, *filtration*, and depriving it of its disagreeable taste, or *disinfection*. The latter operation, when necessary, is always carried on simultaneously with the former.

Natural filter.—At Glasgow the water of the Clyde is filtered by what is called a natural filter. On that river, a few miles above Glasgow, there exists a very extensive convex, round bank of sand; buried in this bank, nearly parallel to the edge of the river as well as to the surface of the water and below its level, a tunnel was constructed, without mortar in the upper part, but with mortar below. The water was allowed to filter into this tunnel

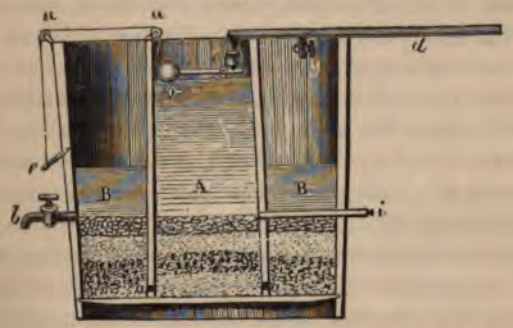
and to trickle from that into wells, and from thence it was pumped up for use. In consequence of the success attending the first great application of this mode of filtration at Glasgow, the process was adopted elsewhere, but generally failed in consequence of the water of springs finding its way into the wells and rendering the river water harder. Another objection to its general introduction rests in the level of the filter being fixed, while that of the river supplying it will vary. In hot weather, when the greatest supply of water is needed, this level is lowest; when there is the greatest demand, therefore, there will be the smallest supply. This kind of filter is likewise liable to clog up with use, and there does not appear any very obvious mode of cleansing it.

Fontaine-filtrante.—Among the water-filterers employed for domestic use, the Fontaine-filtrante, used in Paris, is remarkable for its simplicity, and extensive application. It consists of a box constructed of slabs of a dense stone, often marble, 8 or 9 lines in thickness, connected together by cement. The top is open, and can be covered with a lid; at about $\frac{1}{3}$ of the height from the bottom, a slab of porous stone, called grès-filtrant, is inserted so as to be water-tight, which divides the interior into two unequal parts, each of which is furnished with a cock. In the upper larger chamber, the impure water is placed, and can be drawn off when the vessel requires cleansing by the upper cock; in the meantime, it penetrates the porous stone, and trickles into the lower compartment, leaving its impurities behind, and from thence it can be drawn off for drinking by the lower cock. In order that the air below may escape as the water enters, a leaden pipe is soldered into the lower chamber, which, passing through the whole apparatus, opens above, into the air, and below the lid. No disinfection is effected in this machine, and the filtration takes place from above downwards—a circumstance which always materially impedes and retards the process. The impurities are deposited on the surface of the stone, and there form a deposit of fine mud, which stops up the pores, and in a great measure prevents the free passage of the water. When, on the contrary, the water is forced to permeate the filtering material in a slowly progressing upward current, all that which is freely deposited during filtration falls down, and that portion only, which on account of its lightness and fine state of division, remains suspended in the water, is carried into the filter and remains there. Under similar circumstances, the pores of a filter are much less liable to be clogged

by an upward filtration, than when that operation takes place in the contrary direction, and it consequently requires much less frequent cleansing.

Up- and downward-filtration.—The arrangement shown in Fig. 1, combines in itself both methods of filtration, and has besides several other advantages. It consists of two boxes or cisterns placed concentrically one within the other. In the inner cistern, the filtration is conducted in a downward direction; the water having arrived at the bottom flows through the apertures *a a*, into the compartment *B*, and is thence forced upwards by the column of water in *A* through a second layer of the filtering material until it collects above the cock *b*, whence it can be drawn off as filtered drinking water. In order that there

FIG. 1.



may never be a deficiency of water in *A*, and that it may never overflow, the influx is made to regulate itself, and stop at a constant level. The supply-pipe *d* terminates in a wider pipe *e*, into which a valve is fitted. The plug of this valve rests upon a two-armed lever, the shorter arm of which is fixed by a joint to the mouth of the pipe itself, while the longer arm carries a hollow ball that floats on the surface of the water. If the level of the water sinks, the float sinks with it, as does also the valve, and more water immediately flows in until the proper level is restored. The nature and order of arrangement of the filtering materials is the following:

In the inner cistern, *A*.	In the outer cistern, *B*.
4 inches ofcoarse gravel (at the top).	4 inches of coarse gravel (at the top).
4 „ „ „ sand.	5 „ „ „ sand.
4 „ „ fine river sand, with fragments of wood charcoal, of the size of a pea.	10 „ „ fine river sand (at the bottom.)
7 „ „ fine sand (at the bottom).	

All the kinds of gravel and sand must be carefully washed from all matters that can be held in suspension, and must consist of such materials as are in no way affected by water, for instance, quartz. The coarse gravel (comprising stones of the size of a pea or hazel nut) of which the first and last layers of the filtering stratum consist, is intended to hold the middle layers of fine material better together. The wood charcoal, which while fresh, is well known to possess the property of removing substances having taste and smell from liquids, is the disinfecting agent. Although an apparatus of this kind requires a change of the materials from time to time, and more particularly of the charcoal, yet the mode of its arrangement admits of cleaning without always renewing the filtering materials. This is performed by conducting the water through it in a contrary direction, and thus forcing it to carry with it the impurities which had been deposited during its ordinary course of action. When this operation becomes necessary, the string attached to the peg *f*, and passing over the rollers *u u* is moved, which, lifting the float, permanently closes the valve at *e*, the cock *b* being then shut, and the water let off by the pipe at *i*, a current is passed through the apparatus by opening the cock *y*. The water now penetrates through the materials in *B*, and carries the impurities into the compartment *A*, whence they flow off through the pipe at *i*. When the water issuing from the pipe *i* appears as pure as that supplied at *y*, an opposite direction of the current is again established.

Filters of this description, in which filtration is very much accelerated by hydraulic pressure, may be constructed to any scale, and when the dimensions are large, brickwork is found a more advantageous material than wood.

Cisterns in Venice.—In Venice filtering cisterns of very simple construction are in use. A pit, Fig. 2, is lined with clay *a a*,

FIG. 2.

so as to form a water-tight reservoir *b b*, and this is then filled with sand. In the centre a shaft *c* constructed of bricks without mortar, is sunk through the sand, apertures being expressly left in the internal layer of bricks, through which, and through the crevices between the bricks, the water penetrates after passing through the sand. A bucket or a pump is generally worked through the shaft *c*. The rain water collecting on the roofs of the houses is carried by an annular channel *e e* to the upper layers of sand, sinks down, and is filtered in passing, ascending again in the shaft, from whence it is removed by the pump or by buckets.*

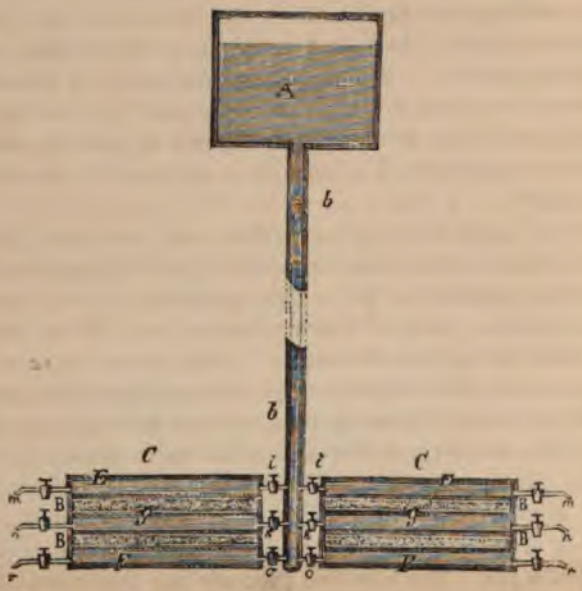
Filtering apparatus at Pont Marie.—At the Pont Marie in Paris, the water of the Seine is not allowed to flow directly into the filtering apparatus, but is first pumped up into four large reservoirs of oak, each of which contains from 800 to 900 cubic feet. Here the water is allowed to remain at rest for some hours, when a considerable proportion of the impurities are deposited, The partially purified water is then pumped into another reservoir, in which the current is regulated and the water equally distributed over the filtering cisterns. These latter contain broken stones (of the same kind as those with which Paris is paved), gravel, consisting of pieces of the size of a nut, and charcoal in pieces of the size of a pea. The filtration proceeds in a downward direction, but the water is not allowed to flow directly upon the sand, but made to pass first through three pipes, at the extremity of each of which a sponge is inserted. This very judicious arrangement is often practised, the sponges being easily changed and cleaned, while they retain a very considerable portion of the impurities.

Fonvielle's filter.—Among the most effective filters is that of Fonvielle, which is erected in the Hôtel Dieu of Paris, and in other localities. Its great efficacy is due to the ingenious application of a powerful hydraulic pressure. The water is conducted from the depositing reservoirs into a supply reservoir *A*, Fig. 3, which is situated 40 feet above the filter. From this height the water descends with considerable pressure through *b*, between the two filters *C C*. The filters consist of strong boxes bound with iron, each of which is separated into five compartments by four pierced shelves. The two compartments *B B* are filled with filtering

* This method might be advantageously adopted in this country, where it has been estimated that as much rain falls on the roof of an ordinary house as will supply nearly all the purposes of its inhabitants.

materials, in the lower part with fine gravel, then fine sand, coarse sand, and lastly with the same gravel as below. The compart-

FIG. 3.



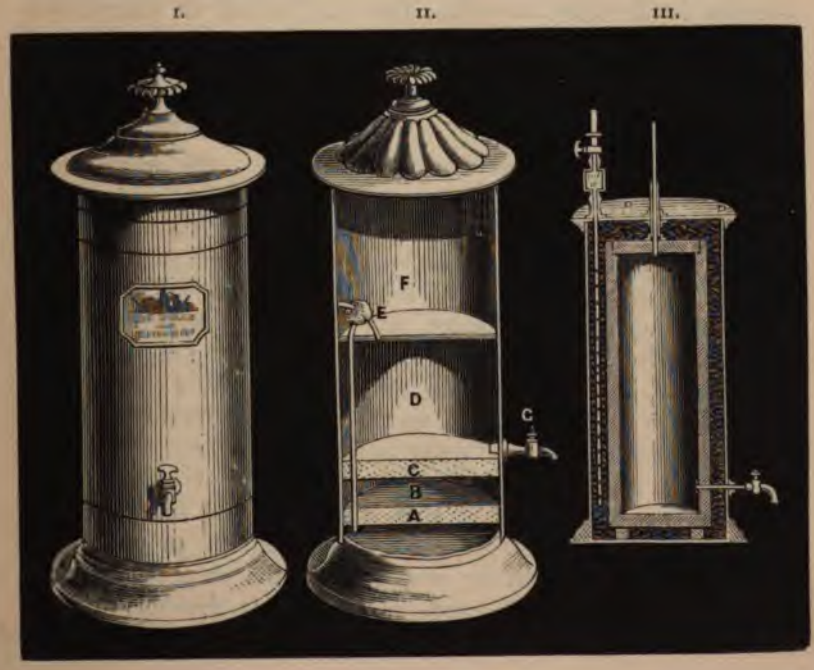
ments $B'B'$ contain the same layers, but ranged in a contrary order; the three other compartments of each box are empty. When the apparatus is at work, the cocks $i\,i$ and $o\,o$ are opened, through which the water enters the empty receptacles $E\,E$ and $F\,F$ with considerable force to penetrate the two filtering compartments B and B', from whence it collects in g, and is drawn off for use by the cocks $n\,n$. The filter is washed every evening by reversing the direction of the current through the compartments. The water is then allowed to enter through the cocks k into the two middle compartments $g\,g$, and having passed through the filtering layers $B\,B'$, is drawn off from the upper compartments E by the cocks m, and from the lower F by the cocks r.

The pressure corresponds to 35 inches of mercury, or $1\frac{1}{4}$ atmosphere, which is sufficient to drive the impurities to a considerable distance into the layers of sand where they are more dispersed, and the filter is not so liable to clog as if they collected on the surface alone. On one occasion, when the water was measured, 6 cubic feet were obtained per minute, although the filter

presented not quite 4 square feet of surface. This amount diminished gradually to 3 cubic feet, a quantity still 17 times greater than is afforded by any of the ordinary filters. It is obvious that a quantity of charcoal can be added to the filtering materials in Fonvielle's filter as easily as in any other.

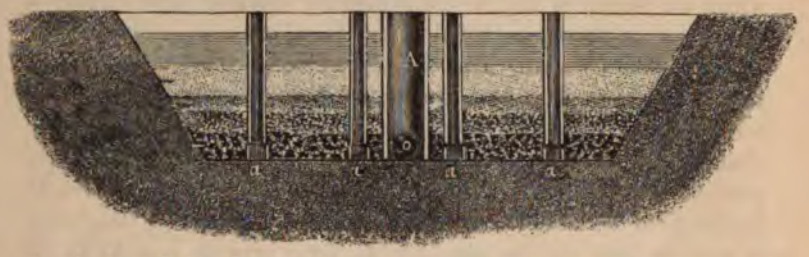
Messrs. Ransome and Parsons have patented an excellent purifier or general filterer for domestic use, different drawings of which are shown in Fig. 4. The filtering material here employed is a kind of porous artificial stone, to which may be added any chemical disinfectant. The drawing II. (Fig. 4) represents a section of the filter, in which the space *F* is occupied by the unfiltered water; *E* a pipe by which the water is conveyed to the chamber at the bottom of the purifier; *A*, *C* are two discs of patent filtering stone; *B* a space between the filtering stones, to be occupied by a chemical disinfectant, through which the water is made to pass into the chamber *D*, from whence it is drawn off by the cock *G*. The drawing III. represents a purifier constructed for high pressure, the water being forced from an outer casing into an inner chamber, through the walls of filtering stone.

FIG. 4.



Filtration of water for manufacturing purposes.—The filtration of water in the calico printing establishments of England may be taken as an example of the manner in which this operation may be effected for all similar purposes, where the water is not required for drinking. A basin 5 feet deep, and from 40 to 60 square feet superficies, Fig. 5, is dug in a high part of the premises,

FIG. 5.



bricked and lined with clay to prevent any loss of water. At the bottom of the basin from 10 to 12 inch channels *a a a* are constructed with bricks, the crevices between which are left open, in order that the water, after passing through the filtering layers, may enter these channels and flow off. Eight iron pipes 6 inches in diameter, ascending above the level of the water in the basin, are connected with these channels for the easy egress of the air. From the channels the water is collected by a cistern or pipe *A*, two square feet in diameter, from which the supply-pipe proceeds.

Chelsea Water-works.—The Chelsea Water-works, where three millions of gallons of Thames water are daily purified, are constructed upon precisely the same principles. The filtration is conducted in a downward direction in reservoirs, which are not excavated, but built up above the level of the ground. The filtering bed takes up an acre of space, and consists, beginning from the upper surface, of fine sand, coarse sand, slate and mussel-shells, fine gravel, coarse gravel. In the last layer, the 8 channels are placed with open crevices and apertures in a downward direction, through which the filtered water passes and collects.

The water is allowed to pour upon the sand at nine different outlets, the upper layer of sand is changed and renewed every fourteen days. The surface being disposed in an undulatory manner, filtration may be carried on in the deeper parts only when less water is required, or when it is desirable to save the filter.

Sponges are not only used as auxiliaries to save the other filtering materials, but also as filterers themselves, a layer of sponge being laid and squeezed together between two perforated boards. Their lightness adapts them for movable filters. Pumice-stone is also a useful filtering material. The advantage derived from allowing the water to settle and purify partially previously to filtration has been already noticed, and the reason why it is not wholly clarified in this manner, and the filters dispensed with, which even in the most perfect arrangement require constant care and attention, arises mainly from the greater length of time which would be required, and is purely an economical question. The water of the Garonne, for instance, at the season of the year when it is most turbid, does not become clear after standing at rest ten days. In order to supply Bourdeaux, it would therefore be necessary to erect reservoirs which would hold ten times the amount of the daily consumption, and these would be far too costly.

Purification by means of alum.—It was an accidental discovery that the purification of water can be greatly accelerated by alum. The mud that water holds in suspension collects, on the addition of 0.0001 parts of alum,* in long thick streaks, coagulates as it were, and is immediately precipitated. This process, the principle of which is inexplicable, was first introduced by the Chinese, and has been imitated in some parts of Europe.† The Parisian laundresses use it—but it has not been introduced into any of the establishments for the purification of drinking water, partly because alum is a substance never naturally contained in water, and may be viewed as a real impurity, and partly on account of public prejudice.

The purification of water by simple standing, is not only impracticable on a large scale from the loss of time it would involve, but also on account of the impurities which are generated by rest alone. In stagnant water to which the air has free access, the lower kinds of vegetation quickly take root; algæ, confervæ, the green matter of Priestley, &c. and numerous classes of infusoria speedily make it their habitation. When the water is more than usually impregnated with organic matter, a putrefactive

* This is equal to 7 grains per gallon.

† This process was well known from a very early period in the Highlands of Scotland, according to Dr. Clark, where it is practised with reference to peat-water.

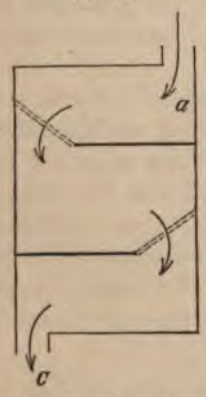
fermentation is induced, which effects a kind of natural process of purification, a portion of these matters being evolved in the gaseous form, and the others precipitated in an insoluble state. The infusoria which inhabit putrid water tend very much to accelerate this process, many of them exhaling oxygen, and thus adding a new agent towards the decomposition of the organic matters.* Filtration through a charcoal filter deprives the water of the matters held in suspension, and also of a portion of the soluble organic matters. According to Bouchardat the soluble portion is very difficult to decompose; if, however, the filtration has not been quite perfect, and the smallest possible quantity of insoluble but suspended matter has passed through the filter, this very quickly again induces putrefaction. For this reason it is better to allow the water so constituted to undergo the process of spontaneous decomposition, as completely as possible before it is filtered. This has often to be done with water for ships' use, but would be quite impracticable on a large scale, from the time it would require.†

Water for ships' use.—The unsuitable nature of sea water for drinking and washing, and the total want of simple, proper appa-

* Water highly charged with vegetable or animal matter may be rendered innoxious in the most simple manner, by boiling. After boiling, it is allowed to stand and cool, and an agreeable freshness may be given to it by the addition of a little soda-water.

† In constructing filters on a large scale, the depth of water allowed to remain above the filtering materials must be carefully looked to, as some kinds of water—for instance the chalk-waters, and still more the sandstone waters—are much more favourable to the growth of vegetable matter than others. The depth of water in this latter case should be increased to 6 feet above the filtering materials, the pressure exerted being counterbalanced by the filtered water. In Lancashire, a pressure of 6 inches suffices where no such growth exists. Reservoirs for water should not be too deep or large, which would encourage vegetation in them, and should yet be large enough to prevent the necessity of taking water, on stormy days, from the rivers, &c., when it is not in a fit state for use. Helps to subsidence should be adopted in large reservoirs, such as partition-walls, which prevent the wind exerting any great agitating influence on the water, and favour subsidence. The walls have the further advantage of thoroughly mixing the water that passes through, no portion remaining stagnant. Covered reservoirs protecting the water from the sun, are less propitious to the growth of vegetable matter. The dotted lines in the figure indicate floating spars with pegs on them for stopping any floating matters that may enter with the water.

FIG. 6.



ratus to remove its saline ingredients compel all ships to provide and carry with them a supply of fresh water, stowed away in the body of the vessel in casks or cast-iron reservoirs. The long duration of sea voyages, the vitiated air of the ship, and the prevailing temperature, render it impossible to prevent the putrefaction and fermentation of the water. Ships leaving London are in the habit of collecting water for the ships' use from those parts of the river, where the drains of the town enter the river and the water is impregnated with organic matter, it being well known that water of this description is subject to a much more violent decomposition, which is, however, at the same time more decided and perfect, and consequently occasions a more complete precipitation of the impurities. That portion of the water that is intended for drinking is purified by filtration through pumice-stone or sponge. It must not be overlooked that during the fermentation, the whole of the oxygen (of the absorbed air) is consumed, and the water has no opportunity afterwards of again making up this loss.*

Professor Clark proposes the removal of a large portion of the carbonate of lime, together with much of the organic and colouring matter contained in river and spring water by means of lime water.

It is well known that the removal of the carbonic acid from water by boiling, causes the deposition of the carbonate of lime, but this may also be effected by any other agent that will remove the acid; for by its agency alone the carbonate is held in solution. Lime water, therefore, or milk of lime added in such quantity to water, as will neutralize the carbonic acid it contains, must remove the solvent, and forming with it at the same time carbonate of lime, both this and the portion originally in solution will be precipitated. Dr. Clark is of opinion that this process might be effected by water companies on a large scale at a trifling expense, prior to the distribution of the water to the consumers, and this expense would be more than compensated by the saving in the wear of clothing, in the consumption of tea, and of soap, while all the other advantages of soft water would at the same time be secured. For the supply of boilers in locomotives, &c., it would appear that this process should well repay the additional

* Most ships in the Thames are now supplied with filtered water from the Lea.

trouble, as a great part of the incrustation would be prevented by the use of this soft water.

The quantity of lime water that is requisite for reducing the hardness will vary with the character of the water to be softened. The waters supplied to the inhabitants of London by the water companies, vary from about 12^0 to 16^0 of hardness, or contain from 12 to 16 grains of chalk per gallon; lime water, containing 98 grains per gallon, or 14 in 1000, added to these in about the proportion of 1 volume of the former to 11 of the latter will reduce the hardness of the water to 4^0. Boiling must be kept up for $2\frac{3}{4}$ or 3 hours with this water, in order to bring it to the same condition, as respects hardness, as is effected by the lime water. The liming process has been put in practice in one of the largest calico print works in Manchester, where the water was not a particularly favourable one for the trial. The incidental property of the process in freeing water from organic matter was the principal inducement to try it in this instance, and in this respect it is declared decidedly satisfactory, while great advantages were likewise derived from the softening action. Several hundreds of thousands of gallons were treated daily in this experiment, and the parties concerned express themselves as having not the slightest doubt that the process would work well on the largest scale.* It is proposed, in carrying out the plan, to allow the water to be purified, and the lime water to flow into a common channel, in the proper proportions, where, running together for some distance with considerable velocity, they will become thoroughly mixed and incorporated with each other, and about 16 hours for water of 10^0 hardness, and less for harder water, must then be allowed for the deposit to settle down to the bottom of a large reservoir.

The influence of the natural constituents of water in its various applications in the arts is fully explained in the course of this work; it is therefore only necessary to advert here to those points, which are connected with the supply of water for domestic and other purposes.

The Board of Health requires that water introduced into any town should be of average good quality, and a knowledge of the following three points respecting it is deemed essential. 1. The degree of hardness, by Professor Clark's test; according to which

* Homersham's Review of Report of Board of Health, 1850, p. 53.

each degree of hardness stands for as much hardness as would be produced by one grain of chalk per gallon, and this point is ascertained by determining the amount of soap test (solution of a definite quantity of soap in alcohol) required to produce a lather with a given quantity of the water.* The water supplied to London averages from 12° to 16° of hardness, or contains from 12 to 16 grains of chalk per gallon.

2. The degree of alkalinity; this is ascertained by testing how much of an acid, of definite strength, is required to render the water neutral. For each degree of alkalinity a gallon of water will neutralize as much of any acid as a grain of chalk would neutralize.

These two tests combined will indicate the relative amounts of neutral earthy salts, and of alkaline earthy salts contained in any water. The soap test indicates the total hardness of any water; that is, the hardness due both to neutral and alkaline earthy salts. The test acid indicates the amount of hardness that is due to alkaline earthy salts. For instance: East London water, May 14, 1841, was $16\frac{1}{10}$ of hardness; it indicated of alkalinity $15\frac{6}{10}$; that is, it required as much acid to neutralize its alkalinity as $15\frac{6}{10}$ grains of chalk per gallon would require; the difference $\frac{5}{10}$, is the utmost quantity that can be due to neutral earthy salts.

3. The total amount of solid constituents and of organic matter per gallon.

Action of water on iron and leaden pipes.—The action of water upon conduit pipes is of much importance, and especially, as these are frequently very extensive.

Ordinary grey cast-iron is subject to slow oxidation, the products of which assume the form of nodular protuberances, which materially reduce the internal diameter of the bore of a pipe conveying water. A water service pipe delivered at Grenoble 90 cub. feet per minute when new, a quantity, which, from this cause, was diminished one half in the course of seven years. The nodules were above an inch thick, of a greenish-yellow colour, magnetic and crystalline in texture. Berthier found them to consist of: protoxide of iron 21.0, xide of iron 58.0, carbonic acid 5.0, water 14.5, silica 1.3. They contain also, a black,

* The special details of the mode in which this and the following tests are to be applied will be found in a specification of Dr. Clark's process for purifying water, published in the "Repertory of Patent Inventions" for October, 1841.

pulverulent substance, and can be produced at pleasure with distilled water, to which a trace of carbonate of soda and common salt have been added, but not with an addition of caustic alkali. They are most easily obtained from grey cast-iron, and only with difficulty from the white variety. Lead is also attacked by some waters, and the waters then contain lead in solution; according to Yorke, oxide of lead is actually soluble in pure water (from $\frac{1}{7000}$ to $\frac{1}{12000}$). The fact, which was observed at the same time, that a gas recognised as hydrogen, collected in the upper part of the curvatures in the pipes, and was in perceptible quantity when the current of water was stopped, has led to the supposition that the lead was oxidized at the expense of the water. When the water contains sulphate of lime, the oxide of lead is precipitated on the inner sides of the pipe as sulphate of lead, and no lead is carried forward by the water. The more air there is dissolved in the water, the more powerful is its action upon lead, and rain water is of all others the most active. Earthenware and glass pipes are not at all affected by water.

The action of water on lead is an important topic, because it has happened in some places that a water has been selected for the supply of a town, which was found to corrode the leaden pipes, and exert an injurious action upon the health of the consumers.

Dr. Clark, in his evidence before the Board of Health, states, that from his own observations, and from published investigations upon this subject, he is of opinion chemists are not prepared to speak with much confidence as to the cause of the corrosion. It is his own and the general impression, however, that the corrosion is due to free carbonic acid. Distilled water is known to act powerfully on lead, and this he attributes to the remarkable property that distilled water, compared with ordinary water, has of dissolving free carbonic acid. Free carbonic acid is most frequently found in water that contains little or no bicarbonate. Cases have occurred at Bagshot, at Haddo House, in Scotland, belonging to Lord Aberdeen, and at Claremont, where bad effects have resulted from the use of water of this description. The whole of the lead can, however, be removed by filtration through sand. It is considered dangerous to allow water to pass through any considerable extent of leaden pipes, or to allow water to remain for a long time even in short pipes. When the supply from pipes is constant, and the use of the stop-cock very frequent, little danger is to be apprehended; but lead can often be detected in water

drawn from a cock that has been out of use for some days, but disappears when the water has been allowed to run briskly from the stop-cock for a few minutes.

Ice.—In the civilized countries of the hot and warmer parts of the temperate zone, ice has long since become one of the common wants of the people. Although this may partially be attributed to luxury, yet on the one hand, a deeply-rooted and universal custom may well be construed into a want, and on the other the application of ice to medical purposes, for the local application of cold, is most useful and essential. Ice has for these reasons become the object of a very extensive traffic, and its preservation a problem for technical ingenuity.

In the preservation of ice, the main point consists in protecting it from the melting influence of the summer atmosphere, for which object the following principles must be carefully attended to :—

The temperature of the earth is uniform at a very moderate depth below the surface, where of course, the heat of summer no longer exerts its influence. The more limited the surface of the ice exposed to the penetrating heat, and the greater its bulk, the less is it liable to melt. Ice-stores should, consequently, not be too small, and the ice should always be closely and densely packed. The external heat exerts very little direct action on the ice, but is chiefly communicated by the currents of air in its immediate neighbourhood, and from the water which penetrates from without, or becomes formed in the interior of the ice-house. The access of heat can be likewise very much impeded by surrounding the ice with non-conducting materials. Very little air should be left in the ice-cellars, and these should be kept as full of ice as possible, and no entrance afforded the external air, or the surface water. For these reasons, ice-houses have generally a northerly aspect, and are, in fact, excavated ice-cellars. A great advantage is gained when they can be shaded by trees or bushes, or are situated under buildings. When the latter is not the case, it is necessary to roof them in, that the warm rain water may not penetrate. Snow is little adapted for preservation, on account of the large quantity of air it contains. A thick layer of straw must, in all ice-houses, separate the ice from the sides; and when the entrance is from the side, and not perpendicular, a double door must be supplied, that the external air may not enter. The surrounding temperature being always above the freezing

point, a certain portion of the ice must necessarily melt, and the water thus formed is generally carried off by some contrivance, although it would be better to allow it to remain, as the air which takes its place must necessarily be warmer than the water, or above 0° C. (32° F.) The drain for removing the water is likewise often the cause of injurious currents of air, cold air flowing out, and being replaced from above by warm air. In many ice-houses salt is thrown in, which, dissolving in the melted ice, causes a further diminution of temperature; the advantage thus gained is, however, seldom equivalent to the extra cost of the salt.

The Neapolitans obtain ice from Vesuvius, but formerly much snow was used in Italy. In Paris, upwards of 300,000 cwt. of ice are consumed annually, of which one-third is supplied by the great ice-house in St. Ouen, at the rate of from 7 to 10 centimes the pound. This ice-house is 40 feet in depth, and 132 feet in circumference.

The ice traffic is carried on with much greater care, and more extensively, in North America. It is imported from thence to the West and East Indies, and within the last few years also to England (Wenham and Silver Lake ice). The source of this ice, which is brought in such large quantities to Liverpool, is a large lake (Wenham Lake), containing the purest drinking water. It is collected in winter, when the coating has acquired a thickness of at least 12 to 18 inches; long strips, 2 feet in width, are first cut with a peculiarly constructed ice-saw, and these are then divided into regular square blocks. The regular form of the blocks admits of their being packed in the smallest possible space in the ship's hold, where they are covered with hay, tan, and wood shavings. In this manner the ice is preserved during a voyage of several months to the East Indies, during which it crosses the line twice, and arrives at its destination with the loss of not more than a fourth of its bulk.

In the United States, the ice-houses are above ground, and consist of two wooden chambers, the one encased within the other, a space being left between the walls, containing a stratum of confined air, which forms the non-conducting medium. Ice, such as that obtained in the manner described above, may be directly mixed with cooling drinks, being itself pure frozen water, while the dirty ice obtained from ponds, &c., in the ordinary way, can only be used for external applications of cold.

MILK.

This liquid, which is prepared and secreted in special organs of the female mammalia, for the nourishment of the young, necessarily contains all the ingredients required for this object. A knowledge of the proximate constituents of milk is of the greatest interest, as affording a practical receipt, furnished by nature for animal nutrition, and this is greatly augmented by its importance in an agricultural point of view.

Milk is a fluid containing insoluble ingredients, held in mechanical suspension, and belonging to the class called emulsions. It is a solution of a small quantity of different salts, with a considerable proportion of sugar of milk, and a nitrogenous substance, *cheese*, or *casein*. In this solution, numerous very small, transparent globules of fat, of different sizes, are suspended. Their diameters vary from $\frac{1}{250}$ to $\frac{1}{850}$ of a line, and can, consequently, only be discerned with the microscope. In consequence of their lenticular action, they disperse the light in all directions, which causes the milk to appear opaque, and white; this, however, is not the case under the microscope. Whether these globules of butter float naked in the liquid, or are encircled, as some suppose, with a covering of casein, is not clearly proved, but the latter opinion appears probable.

Salts of milk.—Milk invariably contains a collection of different salts in solution, which are essential, and vary only in quantity, being always of the same nature. These never amount to 1 per cent of the milk. Haidlin examined the salts in the milk of two cows, and found:

	I.	II.
Phosphate of lime .	0.231 p. c.	0.344 p. c.
„ „ magnesia	0.042 „	0.064 „
„ „ iron .	0.007 „	0.007 „
Chloride of potassium	0.144 „	0.183 „
„ „ sodium .	0.024 „	0.034 „
Soda . . .	0.042 „	0.045 „

The soda, found after the incineration of dry milk, with the other salts, plays the important part of holding the nitrogenous principle, the *casein*, in solution.

Casein.—Pure casein is scarcely soluble in water, it requires

422 parts for solution. Its combinations with the alkalies, on the contrary, are very soluble, and it is in combination with soda that the casein is contained in milk. The addition of a minute quantity of an acid to these compounds of casein separates the soda, and causes the precipitation, or coagulation of the casein. The salts of the earths produce the same effects, for instance, sulphate of lime, which is employed as a coagulating agent in the analysis of milk. When more acid is employed than is requisite to combine with the alkali, the precipitation is imperfect, as casein is soluble in free acids (excepting carbonic and phosphoric acids). The casein, precipitated by acids, has itself an acid reaction, which appears peculiar to it, as it is not removed by water. It neutralizes free alkali, but is unable to decompose the carbonated alkalies. A solution of casein in acids is precipitated by (carbonated) alkali, as is the alkaline solution by acids. According to recent experiments, the casein here described is not a pure body, but a mixture of two different substances. Both are soluble in hydrochloric acid, the one is precipitated from this solution by carbonate of ammonia, and is that to which the above properties chiefly pertain. This substance is far the more abundant of the two, and contains sulphur; the other is not precipitated, and contains no sulphur.

Milk-sugar.—Besides salts and casein, the soluble portion of the milk contains also milk-sugar. After the separation of the butter, and the coagulation of the casein, this substance remains in the aqueous liquid, and can be obtained from it in crystalline masses. In common with all the members of the class of compounds known as sugars, milk-sugar possesses the property of being converted into grape-sugar under the influence of strong acids, and by fermentation, into alcohol and carbonic acid. It is the only variety of sugar generated in the processes of animal life,* and of all the sugars is the least soluble, and least sweet. It requires 3 parts of boiling, and twice as much cold water for solution. Its percentage composition is the same as that of grape-sugar (*i. e.* 40.46 carbon, 6.61 hydrogen, and 52.93 oxygen), but it is distinguished from all the other varieties of sugar by affording mucic acid, by oxydation. The constituent elements must consequently be arranged in a different manner. On the application of

* Diabetic sugar is a rare product of a diseased function of the kidneys.

heat, milk-sugar loses 12 per cent of water, and a crystalline substance is left, which is anhydrous milk-sugar, and which is capable of re-assuming the water which had been evolved. An important practical point in the history of milk-sugar, is the ease with which it is converted into lactic acid. It is to this conversion that the acidity of sour milk is due. Lactic acid plays a very important part in organic nature; it is present almost always where organic bodies are undergoing slow decomposition, in the viscous fermentation, and is also found in the different fluids of the animal frame, and in flesh. From the comparison of its composition with that of milk-sugar:

1 equiv. milk-sugar . . . $= 12\,C + 24\,H + 12\,O$,
2 equivs. hydrated lactic acid $= 12\,C + 24\,H + 12\,O$,

it will be obvious, that the production of lactic acid is not attended by the loss or assumption of any elementary constituent, but is solely due to a re-arrangement of the elements of milk-sugar. This transformation is incited, in milk, by an incipient decomposition of the casein.

Butter.—The fatty part of the milk, which constitutes the chief ingredient of butter, is allied, not only in outward appearance and properties, but also in its chemical constitution, to the other fats, the general characters of which were previously described (Vol. I, pp. 103 and 442). It is composed of three fats: a solid, a liquid, and another peculiar kind of fat, which is called butyrine. The last consists of the oxide of glyceryl, combined with the three volatile fatty acids of butter, *butyric, caproic,* and *capric* acids. The solid fat is margaric acid (no stearic), the liquid oleic acid, both combined with oxide of glyceryl. The former is, therefore, margarine, the latter a kind of oleine. The peculiar flavour of butter is due to the butyrine it contains.

The acids in butyrine have the following composition:

Butyric acid. . . . . $C_8\,H_8\,O_4$
Caproic acid. . . . . $C_{12}\,H_9\,O_3$
Capric acid . . . . . $C_{18}\,H_{14}\,O_3$

The constituents of milk here enumerated are so distributed, that on an average $\frac{1}{200}$ of their weight consists of saline matter, $\frac{1}{30}$ butter, $\frac{1}{20}$ to $\frac{1}{25}$ milk-sugar, about the same quantity of casein, and nearly $\frac{9}{10}$ of water. These relations vary with the breed, with

the age of the calf and of the cow, the mode of life, and the food. The milk first drawn from the udder is likewise different in quality to the latter portions, and the quantity obtained is also as variable as the quality of the milk.

Quantity of milk yielded.—On the estate of M. Boussingault, at Bechelbronn, seven cows were kept, during a year, under the closest observation, with reference to the amount of milk they would yield. Each cow received 33 lbs. of hay, or a proportionate feed of roots; they gave, together, 3966.8 gallons of milk, during 302½ days. The mean quantity of milk yielded by each cow, daily, was consequently 7.2 quarts, but so unequal was the yield, that during the months of July and August, above 11 quarts were obtained, whereas the average amount during the months of February and March, did not exceed 4.2 quarts daily. From similar observations upon only one cow the daily yield, during the time that the cow gave milk, was 6.4 quarts. If 4.2 quarts be taken as the least, and 11.2 quarts as the greatest quantity of milk produced by a cow, the daily yield would average:

10.3 lbs. to 29 lbs. of milk:

of which about

5	to 13.9	oz. are butter,
7.5	to 21.35	„ „ milk-sugar and soluble salts,
8.4	to 23.65	„ „ cheese and insoluble salts,
Total 1 lb. 5 oz.	to 3 lbs. 11 oz.	of solid matter.

Every agriculturist is well aware, that as far as fodder is concerned, cows give the largest quantity of milk when fed upon green food, and *vice versâ*. In other respects, provided a sufficient quantity of food is given, it does not appear to influence the milk so much as might be expected.

Boussingault and Le Bel arrived at this conclusion, at least as far as the quantity of milk is concerned. R. D. Thomson, on the contrary, was led by similar, and also very extensive observations, to the result that the yield of milk, and the amount of butter contained in it, varied with the amount of nitrogen (the plastic constituents) of the food. He exemplified this result by the following table, in which, during a period of 5 days, the mean quantities obtained from two cows are recorded. Grass is the only food which forms an exception to the rule.

Kind of food.	Milk in pounds.	Butter in pounds.	Amount of nitrogen in the food per cent.
Grass	114	3.50	2.32
Barley with hay	107	3.43	3.89
Malt with hay	102	3 20	3.34
Barley, syrup and hay . .	106	3.44	3.82
Barley, linseed and hay . .	108	3.48	4.14
Beans with hay	108	3.72	5.27

Another table exhibits, in a similar manner, the amount of solid ingredients in the milk (dry residue) for another period of five days.*

Kind of food.	Grass.	Barley with the husk.	Malt with the husk.	Barley without husk.	Malt without husk.	Barley with molasses	Barley with linseed.	Beans.
		pounds.	pounds.	pounds.	pounds.	pounds.	pounds.	pounds.
Dry milk (water deducted)	29.64	25.57	24.82	28.12	2.61	25.69	27.48	27.00
Butter . . .	5.96	5 56	6.56	6.87	6.43	7.0	7.0	7.5

The milk was composed in 100 parts, of water 87.19, butter 3.70, sugar 4.35, casein 4.16, soluble salts 0.15, insoluble salts 0.44.

The fact, that not only the yield in milk, but also the amount of butter in it increases with the amount of nitrogen in the food (*i. e.* with the quantity of plastic food), is the more remarkable, as the absence of nitrogen in butter would naturally have led to a contrary conclusion. Playfair was led by his experiments to the result, that food containing no nitrogen (as potatoes) yielded a large quantity of milk which was rich in butter, and that quiet (stall-feeding) had the same effect, whilst cows grazing in the open air upon poor pasture, and consequently obliged to take much exercise, yielded milk rich in casein; his experiments, however, were conducted during too short a time, and too casually, to be entirely depended upon. It also appeared from Thomson's observations, that the yield of milk of a cow with uniform diet, as for instance, only barley as food, gradually diminished and increased again by a change of diet. A frequent change of food is consequently advantageous. As a general rule,

* The figures in the table were originally the mean out of the five to fourteen days' observations on two different cows; for the sake of comparison, they are reduced to five days.

also, the morning milk was found richer than that of the evening. Thus, with hay and barley feeding, it was found as follows:

	1. August.	2. August.	3. August.	4. August.
Morning .	$11\frac{1}{2}$ lbs.	$11\frac{1}{2}$ lbs.	$11\frac{10}{16}$ lbs.	$10\frac{14}{16}$ lbs.
Evening .	$10\frac{1}{3}$ „	$9\frac{11}{16}$ „	$9\frac{11}{16}$ „	$9\frac{11}{16}$ „

As Playfair analysed the milk each time, his results afford a general view of the variations, which occur with reference to quantity.

Fodder.	In the	Day.	Casein. p. c.	Butter. p. c.	Sugar. p. c.	Ash. p. c.	Water. p. c.	Quantity. lbs.
Morning after grass	open air	1st.	5.4	3.7	3.8	0.6	86.5	7.31
Evening „	„	1st.	3.9	5.6	3.0	0.5	87.0	10.94
Evening „	stall	2nd.	4.9	5.1	3.8	0.5	85.7	8.51
Evening, hay, oats, beans	„	3rd.	5.4	3.9	4.8	0.5	85.4	10.54
Morning, hay, oats, beans	„	3rd.	3.9	4.6	4.5	0.7	86.3	11.61
Evening, potatoes	„	4th.	3.9	6.7	4.6	0.6	84.2	12.90
Morning, „	„	4th.	2.7	4.9	5.0	0.5	86.9	10.32
Evening, hay, potatoes.	„	5th.	3.9	4.6	3·9	0.5	87.1	13.18
Morning, „ „	„	5th.	3.5	4.9	3.8	0.5	87.3	12.20

The amount of milk yielded is also dependent upon the breed of the cattle.* Good ordinary cows yield in this country from 8 to 12 quarts daily. The average daily produce of dairy cows, according to the county surveys, amounts in

	quarts.		quarts.
Devonshire to	12	Lancashire	8 to 9
Cheshire	8	Ayrshire	8

the best Ayrshire kyloes yielding on an average $12\frac{1}{2}$ quarts for ten months during the year.

A much larger quantity of milk is yielded in the first two months after calving than at the subsequent periods: the decrease is stated as follows, according to Ayton:

	quarts per day.		quarts.
First fifty days	24	or in all	1200
Second „	20	„	1000
Third „	14	„	700
Fourth „	8	„	400
Fifth „	8	„	400
Sixth „	6	„	300

* Johnston's Agric. Chem.

and, at the end of ten months, they become altogether or nearly dry.

The first milk that comes from the udder, before the calf has sucked, is 5 times as rich in casein as that which follows.

When the milk, at one milking, is collected in several vessels consecutively, the last portions are found to contain more cream than the first, in the proportion of 16 to 1 (Anderson). Schübler collected milk in 5 consecutive portions in separate vessels, and found:

	1st portion.	2nd portion.	3rd portion.	4th portion.	5th portion.	Mean.
Specific gravity . .	1.034	1.0334	1.0327	1.0315	1.0290	1.0321
Percentage of cream.	5 p. c.	8 p. c.	11½ p. c.	13½ p. c.	17.5 p. c.	11.0 p. c.

The last portion that flows from the udder contains, therefore, 3½ times as much cream as the first. In an experiment of Quevenne, this relation was as 1 to 2⅔. Cows' milk, fresh from the udder, generally exhibits an alkaline reaction; it is only acid in exceptional cases, or after standing for a long time.

For the sake of comparison, the following analyses of milk from different sources are collected:

	Woman's milk.		Asses' milk.	Goats' milk.
	good.	bad.		
Butter . .	3.4	1.3	1.29	4.56
Milk sugar .	4.3	3.2	6.29	9.12
Casein . .	3.1	2.7	1.95	4.38
	Haidlen.		Peligot.	

Blue milk.—A remarkable phenomenon, which has been frequently observed, is the blue colour of some milk: thus, Bailleul observed in the neighbourhood of Havre and Yvetot, that of two cows fed in the same stall, the one gave good, the other blue milk. The blue colour appears often only in parts, and is caused, according to some, by microscopic vegetation, according to others, by an infusion-animalcule (*Vibrio cyanogenus*), as, in other cases, the milk assumes a yellow colour from the *Vibrio xanthogenus*. The smell, taste, and even colour of different kinds of fodder, more particularly of turnips, are well known to be communicated to the milk.

Butter, cream.—When milk is allowed to stand for some hours, a thick liquid, or *cream*, comes to the surface and separates from the thinner, more watery milk, in the lower part of the vessel.

Cream is a collection of the specifically lighter globules of butter, which on account of their small size and the thick character of the liquid, can only rise to the top after a considerable period of rest. The globules of butter in cream are always separated from each other, and surrounded by the soluble ingredients of the milk, while the milk itself never becomes perfectly clear in consequence of retaining a certain proportion of these globules, so that cream may be viewed as milk rich in butter, and the serum as watery milk containing but little butter.

Lassaigne has shown that milk, taken immediately after the birth of the young, throws up the most cream, which quantity then gradually diminishes. 1000 volumes of milk afford, according to him:

Days after birth of young.	1.	4.	6.	20.	21.	30.
Cream . . .	200	200	188	78	59	64
Serum . . .	800	800	120	922	141	936

The following quantities of cream and butter were yielded by a dairy of 38 cows in Ayrshire* during 6 several days, November and December, 1843:

Date.	Cream in imp. gallons.	Butter in pounds.
November 1	16	43½
„ 7	19¼	47½
„ 14	18¾	43
„ 21	21¼	47
„ 29	18	39
December 7	19	43½
In all	112¼ gallons gave	263½ lbs.

or seven quarts of cream in November gave four pounds of butter.

A second spontaneous change which milk undergoes on standing, is that of turning sour, which is speedily followed by coagulation, or the deposit of the casein. For this reason also, the total separation of the cream is not practicable, as it is stopped by the thickening and souring. It has been observed that milk kept in zinc vessels remains sweet 4 to 5 hours longer than in wooden or earthen

* Johnston's Agric. Chem. p. 957.

vessels, and that the use of zinc vessels consequently affords a larger produce of cream—the poisonous character of the zinc-salts, however, renders the security of this practice questionable, while, from the facility with which glass vessels can be cleaned, they are much to be preferred; and the use of this material has been promoted in this country by the repeal of the duty.

The glands in the teats of the mammalia which secrete the milk, are vessels interlaced with each other in such a manner as to form a round body, which extends in proportion as the milk is secreted, they are thus reservoirs of milk, in which a separation of the cream takes place from the same causes as in an open vessel. It is consequently of the greatest importance for the manufacture of butter, that the udder should be completely emptied of the last rich portions of the milk, in which the most cream is contained. At a temperature, varying from 10° to 12° R. (55°—59° F.), milk becomes more limpid, and in a fitter state for throwing up cream than at a temperature approaching 0° (32° F.) The dairy should consequently be built in a position where this temperature can be easily maintained during both winter and summer. The application of a greater degree of heat would tend to separate more cream, but also to render the milk sour. Under ordinary circumstances, the cream can be collected for churning at the expiration of from 24 to 36 hours. The first layer of cream which collects after 6 or 12 hours is said to afford richer and better butter than ordinary cream, so that milk is sometimes twice skimmed, the first portion producing butter of better quality than the last. The larger globules of butter, which ascend with greater ease, probably rise first to the surface, and form, on account of their size, a richer cream, and this being formed 6 hours before the rest, the butter is fresher and more palatable.

Cream of ordinary quality is more pasty than liquid, and has considerable consistence, which is augmented by allowing the cream to stand until it has acquired a certain degree of acidity; a liquid whey then separates from it, and the cream becomes relatively more solid.

Berzelius set aside a specimen of milk for the purpose of analysis, during 8 days in a flat dish, exposed to a temperature of +3° C. (38° F.) The milk was then separated from the cream by a syphon, and both were examined.

The milk (sp. gr. = 1.0348) contained:		The cream contained:	
Casein (with some butter)	2.6	Butter (by shaking)	4.5
Milk-sugar	3.5	Casein	3.5
Lactic acid and salts soluble in alcohol	0.6	Whey	92.0
Other salts	0.4		
Water	92.9		
	100.00		100.0

According to Luiscius and Bondt, milk yields 4.6 p. c. of cream, a quantity which, however, must necessarily vary.

The proper state of the cream is generally attained in 3 or 4 days, when the process of *churning* is commenced.

Churning.—The churn is a contrivance for stirring and beating the milk for some time, until the butter collects together in the form of a ball, and separates from the sour liquid of the cream —the *butter-milk.*

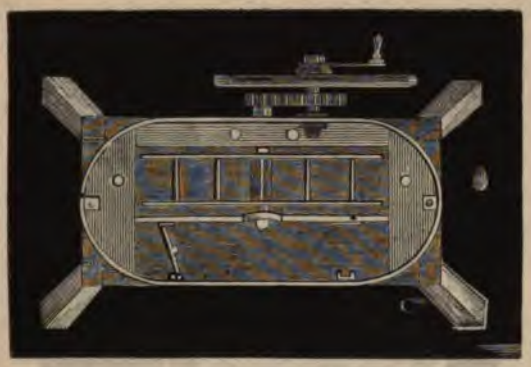
Fig. 7 is a sketch of Rowan's churn: it is an oval tub fixed to

FIG. 7.

a strong framing of wood, divided into two equal parts by a

partition, as shown in Fig. 8, but leaving a passage at each end.

FIG. 8.



The dashers revolve on one side of this partition. The centre is open, allowing a free passage for the air, which is said to improve the quality of the butter. Each end and so much of the side of this centre is covered, as is necessary, to prevent any waste of liquid from the agitation procured by the dashers as they revolve. The motion is communicated in the ordinary way.

The barrel churn, Fig. 9, is generally used in the Gloucester-

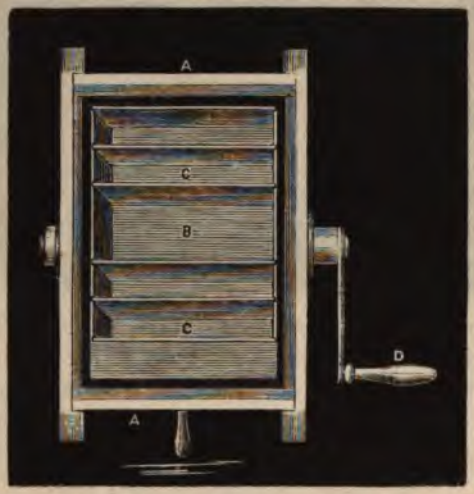
FIG. 9.

shire dairies, being made to hold from 12 to 20 gallons and upwards. It is turned by a handle, and the milk is shaken by the dash-board inside, as it revolves. The interior of the churn

shown in the sketch by the unshaded part, and the opening through which the cream is poured into the churn is indicated at *a*.

Fig. 10 is a sketch of Anthony's improved churn. The churn

FIG. 10.



is of the revolving kind, the dasher-wings having cavities formed in them, so that, in their revolution, they carry down a large quantity of air into the cream. The sketch shows the dashers, the outer case having been removed. *A A* is the case, of the ordinary rectangular form, *B* is the dasher, which may be formed with several arms, but is here represented with two. This is simply a flat board with raised edges all round, the recesses on each side being subdivided into smaller chambers *C C* by transverse bars. The dasher is made to revolve by a winch-handle *D* as usual, the effect of the arrangement causing the air to pass down beneath the surface of the liquid.

In other cases, beating, whipping, or stirring, have a tendency to mix the ingredients of a liquid, instead of causing their separation. Thus, in the preparation of the milk of seeds, the uniform mixture of the oil with the aqueous liquid can only be obtained by similar means to those which, in the case of cream, cause the separation of the butter. This is obviously accounted for by the fat of the cream being *solid* instead of liquid at ordinary temperatures. Any motion communicated to the liquid can, under these circumstances, only cause the globules of butter to adhere closer to each other, and in no way tend to

separate them. Groups of butter globules are first formed, then small lumps, and, lastly, larger pieces, which eventually combine into one solid mass. These remarks render it obvious why temperature is so important an object in churning. In the heat of summer, the butter is too soft, and even sometimes liquid, and consequently will not cohere; if the temperature is too low, the cream becomes very thickly fluid, and a great obstacle is thus presented to the action of the churn. The temperature of the cream must consequently be regulated by cold or warm water, or milk, to about 12° R. (59° F.) In warm summer weather, where cold water cannot be procured, the operation of churning is often very difficult.

Butter-milk is a semi-coagulated solution of casein, which contains butter, partly in globules, partly in larger lumps, the milk-sugar of which is nearly all transformed into lactic acid. The butter contains a quantity of butter-milk enclosed in its substance, for which reason it must be kneaded with water, that this may be washed out as much as possible. With reference to the amount of produce, the following statements will serve as a point of comparison. Boussingault obtained from 100 parts of milk:

Cream . .	15.6 =	3.33	butter,
		12.27	butter-milk.
Skimmed milk	84.4 =	8.93	coagulated cream,
		75.47	whey.
100.0		100.00	milk.

In one year 33,763 lbs. of milk yielded together 982 lbs. of fresh butter, or 3.3 p. c. In other places, these proportions differ. Thus, 5000 volumes of milk, according to Baude, yielded on an average: at Cartigny, near Geneva, 1.6 p. c., and at Chateauvieux, near Geneva, 1.8 p. c. of butter. Quevenne obtained from 109½ lbs. of cream churned at a temperature of 20° C. (68° F.), 30½ lbs. of butter of the best quality, and 79 lbs. of butter-milk. These consisted of:

	In the butter.	In the butter-milk.	Thomson found in butter.
Pure butter .	77.5 per cent.	0.24 per cent.	86.3 per cent.
Casein . . .	1.6 „	3.82 „	0.9 „
Water . . .	20.9 „	90.80 „	12.8 „
Milk-sugar, soluble salts, &c.		5.14 „	

There were, therefore, 3.2 ounces of butter-milk left in the

butter; besides which, about $\frac{1}{16}$th of the butter remains in the milk after it is skimmed, which both together make a total loss of $\frac{1}{2}$ of the butter contained in fresh milk. The separation of the butter by churning is equally well effected in close as in open vessels, the access of air is consequently immaterial, and Macaire-Prinsep has likewise proved that no absorption of oxygen occurs during the operation.

The temperature of the cream when put into the churn should not, according to Johnston, exceed 53° to 55° F., and when the whole is churned it should be raised to 65° F., which is best done by pouring hot water into the churn while the milk is kept in motion.

The two following series of results, obtained in churning cream at different temperatures, and with different degrees of rapidity, prove the importance of attending to these points.

Dr. Barclay and Mr. Allan operated upon 15 wine gallons of cream in each experiment, weighing from 8 to 8¼ lbs.

No.	Temperature		Time in churning.	Quantity of butter per gallon.	Quality of butter.
	beginning.	end.			
			hours.	lb. oz.	
1	50°	60°	4	1 15¼	Very best, rich, firm, well tasted.
2	55°	65°	3¾	1 15⅛	Not superior to former.
3	58°	67°	3	1 14	Good, but softer.
4	60°	68°	3	1 12⅜	Soft and spongy.
5	66°	75°	2½	1 10½	Inferior in every respect.

A temperature of 50° to 55° F., and from 3½ to 4 hours churning, is thus shown to be the most eligible for the production of the best butter. The quality of the cream appears also to differ, and require accordingly different treatment.

The length of time devoted to churning differs considerably in the following series; the experiments were made by Mr. Ballantyne each upon 8 wine gallons of cream, weighing 8 lbs. to the gallon, except that of the fourth experiment, which weighed 4 oz. less.

No.	Temperature of the cream.	Temperature when butter came.	Time in churning.	Quantity of butter per gallon.	Quality of the butter.
			hours.	lbs. oz.	
1	56° F.	60° F.	1½	2 1	Inferior, white, and softer than No. 2.
2	52°	56°	2	2 0	The flavour and quality of these two samples of butter could not be surpassed.
3	52°	56°	2	2 0	
4	65°	67°	½	1 15	Soft, white, milky.
5	50°	53½°	3	1 15½	Good, evidently injured by long churning.
6	53½°	57½°	1¼	2 0⅝	Most excellent ; high in flavour and colour, and solid as wax.

The best quality of butter can therefore be obtained, by churning at a temperature from 50° to 55°, and for a time varying between 1¼ to 4 hours, according to the nature of the cream.

Rancid butter.—The small quantity, $\frac{1}{5}$th or $\frac{1}{6}$th of butter-milk, which remains mixed with fresh butter, is of the greatest importance, as it gives the agreeable taste to the butter, although it tends to prevent its keeping. The semi-coagulated casein in the butter causes it to become rancid in a very short time. This is due to a decomposition of the butter, with the formation of fatty acids, and is accompanied by a nauseous irritating taste, induced, or at least dependent upon, the decomposition of the casein. The pure fat of butter may be kept for months without undergoing decomposition, and when its preservation is therefore required, it is absolutely necessary to prevent the decomposition of the casein, or entirely to remove it. Two methods, equally good, are commonly put in practice with this object. The one consists in *salting* the butter, which preserves it for immediate use by hindering the decomposition of the casein; the other, in *melting* it, which removes the inciting ingredients.

Salting.—The salting process is effected by kneading the butter with common salt, in quantities varying with circumstances, and sometimes with an addition of saltpetre. The quantity of salt usually employed is from $\frac{1}{24}$th to $\frac{1}{28}$th of the weight of the butter. When the butter must be transported to a great distance, a larger quantity of salt is employed, and the butter required for immediate use is washed with water.

Melting.—The melting is carried on in a deep vessel over a slow fire. In the beginning, the melted butter takes the consistence of

an emulsion, and boils; towards the end, however, when all the water is removed, the coagulated cheese separates as a grey mass, *butter-scum*, on the surface, while the butter is in the form of a perfectly clear fat, which after being strained into the preserving vessels, assumes the consistence of lard. Melted butter has neither the consistence nor the taste of fresh butter, but retains its yellow colour. The colour is mainly dependent upon the fodder, but it is unimportant, and increases in summer with green food, and diminishes in winter, when the cows are fed upon dry hay. The butter melted in this manner should always be well preserved from the access of air. Less melted butter is always obtained than should be, according to the quantity of fat contained in it in the fresh state. From 29⅛ lbs. of fresh butter, only 21¼ lbs. of melted butter are obtained, or 73 p. c.

Cheese.—Cheese is equally important with the butter. Unfortunately, the principles of this branch of dairy industry, which has attained a very high practical importance and development, have not yet been maturely studied.

It has already been stated that any acid, and particularly the lactic acid produced from sugar, has the property of rendering insoluble, or coagulating the casein of milk. This coagulation is practically the commencement of the manufacture of cheese, and the innumerable modifications of this process may be described under the two following divisions. The milk is either allowed to coagulate of itself by simple standing from the spontaneous formation of lactic acid, or external means are made use of to produce the same effect, the chief of these being *rennet*.

With reference to the butter, there is also a great variation. In many cases the milk is caused to coagulate in such a manner, that the butter is enclosed by the cheesy matter, and remains mixed with it—*fat, or rich cheese;* in other cases, the cheese is prepared from skimmed milk—*poor, or skim cheese.*

Hand-cheese.—To the latter class belong the hand-cheeses, so common in middle and southern Germany. The milk is set aside to become sour, the acid cream is taken off for churning, and the remainder, the *thick*, or *sour milk*, is used for making cheese; in this, there is naturally not more butter than the skimmed milk has been able to retain. The acidity taking place very gradually under these circumstances, and proceeding in perfect quiet, the particles of cheese are unable to agglomerate, but transform the milk into a semi-liquid mass, which separates like a jelly, on

being poured out. When squeezed in a cloth, a liquid runs from it, "*whey;*" while the casein, "*curds,*" is pressed into a kind of dough. This curd, with the addition of salt and caraway seeds, is formed into balls with the hand, and hung for some time exposed to the air; a very slow process then commences, under the action of the atmosphere, which proceeds from the surface to the interior, and gradually ripens the cheese and renders it fatty throughout. The white curd acquires consistence, and forms a translucent, fatty, yellowish mass, possessing very different taste and properties. Many weeks are occupied in this process, and while the interior, the core, is still unchanged, the outer layers become over ripe, and undergo decomposition. It is then converted into a slimy disgusting substance, emitting the intolerable stench so characteristic of hand-cheese. To prevent, or retard this putrefaction, during the ripening of the cheese, each separate piece must be washed from time to time, and a loss is thus occasioned amounting, no doubt, to ¼th of the entire mass, which at once condemns the whole process.

The celebrated Dutch, Limburg, and Swiss cheeses, are made from sweet instead of sour milk; sometimes skimmed milk, at others, rich milk, or both at the same time are employed in the manufacture; in every case, the coagulation is effected by *rennet.* Rennet is the membrane of the calf's stomach, prepared in a particular manner, which possesses, during the life of the animal, the property of coagulating milk, and retains this property to a remarkable extent after death. All the different methods of preparing rennet, have the common object in view—to protect it from undergoing putrefaction; this is done either by smoking, salting, or by both at once, or lastly, one of the three methods is combined with the use of spices. When rennet is salted in the dry state, it soon produces a salt brine, which also exhibits the property of coagulating milk, and is employed for that purpose. While in many districts, it is the practice to remove the milk that has curdled in the stomach, custom has prescribed, in others, the use of the stomach, together with its contents, as rennet. In the latter case, the cheese is less easily preserved, the butter in the coagulated contents of the stomach having a strong tendency to become rancid. It is remarkable how powerful an action is exerted by a very small quantity of rennet; thus, 1 square inch of smoked and salted rennet, is sufficient to coagulate 80 quarts of milk. In Scotland, for instance, where they do not employ the

rennet itself, but an infusion of whey, or salt water with rennet, a table-spoonful is sufficient to curdle 120 quarts of milk.

The infusion employed in the manufacture of Limburg cheese, obtained by allowing salt water to trickle through the smoked stomach, appears to exert a still more powerful action. According to the statements of the farmers, from 4 to 6 drops are sufficient to coagulate 24 quarts of milk. Whether the acid property of rennet is the sole cause of this power, has not yet been ascertained, and it is to be remarked, that very often acid parts of vegetables, *e. g.* lemons, bramble leaves, &c., are used to assist the rennet, and that that substance, according to all experience, becomes more active by keeping. Berzelius found, that 1 part of rennet only lost 0.06 parts by weight of its substance, in coagulating 1800 parts of milk. It may, however, have lost something on the one hand, and gained an equivalent on the other.

In Cheshire a portion of the dried stomach is put into half a pint of lukewarm water, with as much salt as will lie upon a shilling, is allowed to stand over night, and in the morning the infusion is poured into the milk. For a cheese of 60 lbs. weight, a piece of the size of half-a-crown will often be sufficient, though of some skins as much as 10 square inches are required to produce the same effect.* The entire stomachs are, however, often allowed to infuse for about two days with two quarts of water for each stomach, and the infusion being poured off, is completely saturated with salt.

The coagulation of milk on the large scale, is carried on in cauldrons over the fire, the heat tending very much to facilitate the process. A temperature of 40° C. (104° F.) is sufficient. At a low temperature, the casein is curdled in too porous a condition: it then forms soft, gelatinous flocks, which only separate with difficulty from the whey. If, on the contrary, the milk is hot at the time of coagulation, the flocks of casein cake closely together, become firm, and yield a cheese which is much harder, and requires a longer time to ripen. Soft or hard cheese may, with proper attention to these circumstances, be prepared at will.

When the whey has nearly separated from the curd, the latter is scooped into the moulds, which are so constructed that the last portions of whey can drain away, assisted at the same time by

* Dr. Holland. Quoted in Johnston's Agric. Chem.

pressure. The separation of the whey is a part of the process upon which the quality of the cheese, in a considerable degree, depends. The sugar and lactic acid which it contains would, if not removed quickly, give rise to decomposition in the cheese; and in Cheshire particular attention is paid to this point. A curd mill, for chopping the curd after the whey is strained off, is in use in many large dairies, and an ingenious pneumatic cheese-press for sucking out the whey was invented by the late Sir John Robison, of Edinburgh.*

Season and locality appear to exert great influence upon the amount of cheese yielded by milk; in this country 8 to 10 lbs. of good milk should, in the summer season, yield 1 lb. of whole milk cheese.

Professor Johnston gives the following scheme of the profit of making butter and cheese compared with that of selling the milk.

			Value.
			s. *d.*
90 quarts of milk		sold as new milk	15 0
,,	,,	made into full milk cheese	9 6
,,	,,	made into butter and butter-milk, where the latter can be sold	10 6
,,	,,	made into butter and skim milk, where the latter can be sold	10 5
,,	,,	made into butter and skim milk cheese .	11 6

When the new or skim milk is sold, the expense of churning, or making cheese is saved; and it would appear that, in this country, the most profitable way, if new milk is not sold, is to make butter and skim milk cheese. The cheese acquires consistence after some time, and can be removed from the moulds, and set aside to ripen. During the whole period of ripening, the cheese must be daily rubbed in with salt, or moistened with brine.

There is no doubt that the ripening of cheese, during which it becomes fat, is due to a chemical alteration in the coagulated albumen; this is further borne out by the remarkable fact, that the casein again acquires its solubility in water, with the ripening of the cheese. There is reason to believe that this phenomenon is caused by a decomposition of the salt employed, and attended by the formation of a compound of soda with casein. The forma-

* Johnston's Agric. Chem.

tion of cheese would thus become a re-transformation, a production of solid milk, without milk-sugar.

The butter can be completely removed from fat cheese by ether; it is then in a state of rancidity, and its mixture with casein is, perhaps, effected by the agency of ammonia.

When cheese is kept for a length of time exposed to the air, its surface not being rubbed well with salt, mites are produced, which congregate in the cracks and crevices. A blue mould is also often found growing in cheese, and is considered by many in this country as a great delicacy.

The juice of the butterwort (*Pinguicula vulgaris*) has an extraordinary effect upon milk, coagulating it into a thick, ropy liquid, which can be drawn out in threads, and quite dissimilar to cheese. Milk, in this condition, is taken as food in the northern parts of Sweden (*Tätmjölk*). The vessels in which this action is effected, retain the same power as the butterwort, for a long time, and can with difficulty be deprived of it.

Of milk-sugar.—The production of *milk-sugar* is almost entirely confined to Switzerland, where the shepherds prepare it by evaporating the whey after the separation of the cheese. This whey contains, even after complete coagulation, a kind of nitrogenous matter, which can be coagulated by the addition of acetic acid, at a temperature of 75° C. (167° F.). It is used in Switzerland for the preparation of the cheese called *Zieger*, or *Schabzieger*, and is considered by some to be a sort of casein nearly allied to albumen.

Cause of difference in the taste of cheese.—The process peculiar to the production of cheese must be much better understood in its scientific relations, before the various properties and different tastes of cheese can be satisfactorily explained. The Swiss, English, and the greater part of Dutch cheese, are made from the entire unskimmed milk. Swiss cheese is much sharper, softer, and less aromatic than the English, and is also full of large holes. It has not been ascertained whether these holes are filled with atmospheric air, or with carbonic acid evolved from the sugar in the whey. Limburg cheese is very soft and elastic, in consequence of the curd being formed at a lower temperature and less firmly pressed. Cream-cheese is prepared by mixing an additional quantity of cream with milk previously to coagulating the whole with rennet. Parmesan is one of the best known kinds of skim-cheese. It is generally coloured with saffron, while annatto is the colouring

matter used for rich cheese in England. There is a celebrated kind of cheese, manufactured in the village of Roquefort, in the department of Aveyron, in France. It is prepared from a mixture of goat and sheep's milk, and had acquired great renown as early as the time of Pliny. It appears as if cheese of the peculiar character of that of Roquefort could only be made in the remarkable rock-cellars of that place, which are constantly at a temperature between $+5^0$ and 6^0 R. (43^0 to 45^0 F.). This temperature is due to the joint action of several circumstances, first, the external cold currents of air, which descend constantly into the valley where the cellars are situated from the neighbouring mountains. The limestone rock in which the cellars are excavated is nearly perpendicular, and its aspect is such that the sun's rays scarcely ever reach the entrances to them; but the chief cause of the low temperature lies in the numerous currents of air which are constantly circulating in the crevices of the limestone rock (from large caverns in the interior?). Chaptal observed a thermometer fall in the neighbourhood of one of these currents, from 23^0 R. (84^0 F.), that being the temperature of the air, to 4^0 R. (41^0 F.). The beneficial influence of this cool temperature upon the ripening of the cheese, and the estimation in which this first and essential condition to ensure its good quality is held, may be seen from the fact, that the cellars known by the name of *Delmat Grottos*, which cost in the first instance 12,000 francs, were bought by the present possessor for 215,000 francs, although they are both small and narrow.

It will be obvious that the preparation of cheese and butter in a politico-economical point of view, must be considered as a transformation of milk into consumable articles, that may be transported and consumed at a distance from the place of manufacture. This would not be practicable with milk in its natural state, on account of its unstable nature and the large quantity of water it contains. It is more than probable that the value of these productions might be much increased in the plains of Germany by a better combination of resources and division of labour. At least, experience proves that the small farmer, without means, cannot compete with the better arrangements, knowledge of the art, cleanliness and care, of his richer neighbour, and must always produce an inferior article. The example of the Swiss in this respect is worthy of imitation. In many places they are in the habit of sending whatever milk they cannot themselves consume,

into a kind of common dairy, from whence they receive cheese, &c., in proportion to the amount of milk delivered.

Although cheese may be produced everywhere, yet the preponderance of this branch of industry in one locality, and that of butter in another, is not purely a matter of chance, but is dependent upon the kind of farming which circumstances must dictate, and upon the nature of the food supplied. In the county of Cheshire, 92,000 cows are kept solely for the production of cheese, and this is sold throughout England. The whole may be viewed as a kind of manufactory, in which the cows represent the chief machinery for the conversion of grass into human food. From 16 to 19 lbs. of milk are there employed to produce 1 lb. of cheese. The largest cheeses are made in England and Switzerland, weighing often from ½ to 1 cwt.

Large quantities of cheese are now yearly imported into this country from America, and although not yet equal in quality to those produced at home, are rapidly improving, and very much cheaper.

Composition of cheese.—The following analyses of cheese were made by Mr. Jones in Professor Johnston's laboratory:

	Skim milk cheese, made June 1846, analysed June 1846.(1)	Double Gloucester cheese, made June 1845, analysed July 1846.	North Wilts cheese, made June 1845, analysed June 1846.	North Wilts cheese, made September 1845, analysed Sept. 1846.(2)	Dunlop cheese, made at Wellwood, 1845, analysed 1846.	Lanarkshire brick cheese, made June 1846, analysed July 1846.(3)	North Wilts cheese, made July 1846, analysed Sept. 1846.(4)	North Wilts cheese, made May 1846, analysed Sept. 1846.(5)	Cheddar cheese, made 1845, analysed February 1847.(6)
Water	43.82	35.81	35.58	36.34	38.46	41.55	40.58	44.80	36.04
Casein	45.04	37.96	25.00	31.12	25.87	28.84	28.25	28.16	28.98
Fat . .	5.98	21.97	30.11	28.09	31.86	27.60	27.44	23.04	30.40
Ash. .	5.18	4.25	6.29	4.41	3.81	2.78	3.73	3.99	4.38
	100.02	99.99	99.98	99.96	100.00	102.57	100.00	99.99	100.00

No. 1. Made in the parish of Carnwath Lanarkshire, on a poor, cold, wet, upland moor farm. Dairy 28 cows.

No. 2. From a rich loam, with gravel subsoil.

No. 3. A small cheese, little bigger than a brick, generally eaten when a fortnight old.

No. 4. From a loam, with running sandy-clay subsoil.

No. 5. From strong clay soil, inclined to be very grassy.

No. 6. From a rich deep soil in the marsh near Chedder, Somersetshire.

The saline matter in cheese is only in part due to the milk, as a considerable quantity of common salt and colouring matter are added to the cheese during its preparation. The following results by Mr. Jones show the relative amounts of earthy phosphate and common salt in the ash of cheese, the chloride of potassium being included in the amount of salt. The specimens are the same as those the analyses of which were given above:

	Skim milk. (1).	Double Glo'ster. (2).	Dunlop. (3).	North Wilts. (4).	North Wilts. (5).	½ Ewe milk. (6).
Earthy phosphates in 100 of ash .	54.06	53.64	53.38	64.61	56.42	31.12
Earthy phosphates in 100 of the cheese	2.80	2.28	2.03	2.41	2.25	1.74
Common salt in 100 of the ash .	—	28.70	32.37	16.86	26.28	45.64
Common salt in 100 of the cheese	—	1.23	1.23	0.63	1.05	3.01

No. 1. Made June, 1843; analysed June, 1846.
No. 2. Made June, 1845; analysed July, 1846.
No. 3. Made 1845; analysed 1846.
No. 4. Made July, 1846; analysed September, 1846.
No. 5. Made May, 1846; analysed September, 1846.
No. 6. Made 1846; analysed February, 1847.

The following table represents the percentage of water, ash, phosphates, and common salt found in four other varieties of cheese.

	Skim milk.	Double Glo'ster.	Dunlop.	North Wilts.
Water	55.81	42.37	41.55	36.59
Ash	4.90	5.11	3.38	7.61
Earthy phosphates in 100 parts of ash	52.64	48.60	59.35	—
Earthy phosphates in 100 parts of cheese . . .	2.58	2.48	2.01	—
Common salt in 100 parts of ash	42.13	27.53	—	—
Common salt in 100 parts of cheese . . .	2.06	1.41	—	—

The cheeses were made in 1845, and analysed in 1846.

Preservation of milk.—In the fresh state, at the ordinary tempe-

rature, milk absorbs oxygen from the air which reacts upon the casein and induces the conversion of the sugar into lactic acid. The souring, which occurs in warm weather in a few hours, in one or two days in winter, and more rapidly in stormy weather, may be postponed for three times as long, or even longer, by simply boiling the milk. Gay-Lussac has shown, that by repeating this precaution daily, during summer, the milk may be preserved for months without change. The absorbed oxygen is expelled by this operation and the absorption stopped. The formation of a skin appears connected with this process. Over the surface of boiled milk, a small portion of casein is seen to separate in the solid form as a tough transparent skin, which attaching itself to the sides of the vessel gradually spreads out over the whole surface. This may possibly be the product of the oxygen upon the casein at the boiling temperature. The skin, formed in boiling, acts as a protective coating against the atmosphere. In domestic arrangements this skin is objectionable, as it is often strong enough to prevent the vapour passing off from the boiling milk to escape at once; when at length the opposition is overcome the milk then generally boils over. To prevent this disagreeable coincidence, and the smell of burnt milk, Joumard invented a simple contrivance, or milk lid (Fig. 11). It consists of a lid, sufficiently heavy to resist being raised by the boiling milk, and perforated at *a* in the centre and at *c c*; the skin bursting first in the middle, the milk boils over the centre ring and returns to the vessel through the apertures *c c*.

FIG. 11.

According to the plan of Appert, described further on, milk can be preserved in its original state, but will not bear carriage without becoming churned. The process of Grimaud and Calais, by which the milk is evaporated to dryness by a current of air of the ordinary temperature, and mixed afterwards with water whenever it is used, is certainly too troublesome for execution upon a small scale.

In places where there is a large consumption, the milk is often adulterated, and this is specially the case in Paris, where this indispensable article of food is raised above its natural price by an entrance duty. The ordinary marketable milk is in that town nothing but skimmed milk, with $\frac{1}{4}$, $\frac{1}{3}$, or even $\frac{1}{2}$ water. Cream is

milk in its ordinary state with an occasional extra addition of cream—double cream is the term applied to ordinary cream. Substances added to diluted milk, like the emulsion from hempseed, milk of almonds, yolk of eggs, &c., can easily be detected, and are therefore seldom met with. The same applies to meal and starch. Infusions of rice, bran, and gum are much more frequently used to restore the original thick state of fluidity to diluted milk. One of the most original adulterations is the use of the brain of the sheep, finely rubbed up and separated from the membranes; this masks the presence of water and gives the milk a creamy appearance. When cream of this description is treated with ether, oleo-phosphoric acid is dissolved amongst other substances which, when decomposed with sulphuric acid, yields olein and phosphoric acid, and can thus be detected.

The milk supplied to the inhabitants of London is generally very much adulterated, and brains, according to Mr. Rugg,* is a very common adulteration, besides the large quantities of water and chalk that are added to it. The confined and unhealthy situations in which the animals that supply the milk are kept, and the want of cleanliness in their treatment, often engender disease amongst them, particularly about the udders, so that pus globules may be frequently detected by the microscope among the natural fat globules of the milk. All these are serious evils, and must be very prejudicial to the health of infants and children, who are dependent upon milk for the greater part of their food.

Cow-tree.—A remarkable vegetable production of the equinoctial regions are the *cow-trees* described by Humboldt, Boussingault, and Rivero. Different species of trees are included under this term, which afford an abundant supply of a kind of juice like cow's-milk, and which is frequently used by the natives as a beverage. In the juice of the *Galactodendrum dulce*, which abounds in the Cordilleras, they found: 1), a substance resembling bees'-wax; 2), substance similar to animal fibrin; 3), some sugar and free acid; 4), salts, namely: phosphate of lime, carbonate of lime, magnesia, and silica—all dissolved in water.

Milk-test.—The value of milk consists in the amount of soluble substances (particularly casein), and of suspended globules of butter which it contains. The amount of the former is indicated by the specific gravity of the liquid which is greater in rich than in poor milk. The amount of butter is estimated by the quantity of

* "Observations on London milk."

cream which separates, or by the degree of opacity of the milk. The different milk-tests are all founded upon one or other, or upon both of these qualities at once—they are all however very deceptive and imperfect. If the specific gravity indicated by the hydrometer is taken as the measure of value, an erroneous conclusion is almost certain, as the butter tends to diminish, while the casein augments the number of degrees upon the scale. A specimen of butter may therefore be judged rich in casein, which is only deficient in butter. The mere measurement of the quantity of cream is not only calculated for one ingredient alone, but is inaccurate for this reason, that milk diluted with water throws up more cream than pure milk. There is consequently no method of testing which indicates with certainty fraudulent dilution, the quality of pure milk itself being subject to such great variations.

MEAT—CHEMICAL NATURE.

Butchers'-meat is generally understood to signify the muscular portion of cattle, surrounded by more or less fat, and a proportion of bone. The simple muscular fibres are composed entirely of fibrin (compare pages 4 and 5), but are separated by membrane into bundles, and into larger distinct masses by cellular tissue, in which fat is deposited. The whole is intersected by a net-work, consisting of the ramifications and finest subdivisions of the blood and lymphatic vessels, and of the nerves. It will, therefore, no longer appear strange, when it is stated, that muscular flesh is composed of more fluid than solid parts, and that $\frac{3}{4}$ths of its weight is water. The fat, like the fibre of flesh, is also enclosed in cellular tissue. The following quantitative relations will afford an idea of the structure of flesh. According to Stephenson, a living ox yields 58 per cent of its weight in saleable meat, 8 per cent tallow, and $5\frac{1}{2}$ per cent skin. It was also found by:

	Coke.	Anderdon.	
That a lean living ox yielded . .	60	$53\frac{1}{2}$	per cent
„ moderately fat ox yielded	65	55	of its
„ very fat ox yielded . .	70	61	weight

of marketable meat, and this may be estimated to contain on an average:

10 per cent of dry bone.
5 „ „ cellular tissue and fat.

16 per cent of muscle (with all the soluble matters in the blood, lymph, &c.)
71 „ „ water.

Pure muscular flesh, without visible fat, contains 74 parts water, and 26 parts solid flesh, in 100 parts. Dry muscular fibre, artificially deprived of fat, contains 15.2 per cent nitrogen, and only 14 per cent in the natural state. Hence the amount of fat in the actual meat, when deprived of all the visible fat, would be calculated at 8 per cent, or about $\frac{1}{11}$th of the mass of the muscle.

Chemical nature of the constituents.—In the chemical investigation of meat for practical purposes, as also in its consumption as food, it would be useless to dissect it into its anatomical constituents. The following results apply, consequently, to the entire substance of flesh, and afford a sufficiently clear idea of its nature as an article of food, although a very inadequate definition of it as an organ of the living animal. The anatomical relations prove that meat must consist of:

Fibrin (in the muscular fibre and blood), *Albumen* (in the blood and lymph), *Gelatin* (in the cellular tissue, muscular coats, sinews, cartilage, &c.) and *Fat*. Besides these, there are several other ingredients, which although in small quantity are of great importance; these will be noticed hereafter.

One portion of the substances above enumerated is insoluble in the water of the meat, while the other is soluble, constituting the *juice*. The albuminous matters in the latter are coagulated by a boiling temperature, the others are not; thus the muscular flesh of the ox deprived of fat and bone consists (according to four observers) of:

Fibrin with cellular tissue, vessels, and nerves. .	15	to	18	p. c.		insoluble.
Coagulative portion (albumen and blood-fibrin) . .	2.2	„	4.3	„	}	in solution.
Portion permanently soluble .	2.8	„	3.1	„		
Water	77.0	„	77.5	„		

It must here be remarked, that the researches of chemists have proved a most remarkable similarity to exist in the constitution of the flesh of different animals, notwithstanding the great differences in point of flavour that are discerned by the fine organs of the gourmand. The amount of water in fish does not vary more than 3 per cent from the above statement, and in the meat of

the calf, swine, of game, and poultry, there is still less difference. The main difference lies in the taste, and this can only be attributed to very small quantities of some substances at present unknown; the amount of fat is naturally very variable. Muscular flesh also exhibits the same elementary composition as blood, thus there have been found in

	Dry flesh.	Dry blood.
Carbon . . .	51.83	51.89
Hydrogen . . .	7.57	7.59
Nitrogen . . .	15.01	15.05
Ash . . .	4.23	4.23

so that blood may very appropriately be called liquid flesh, and *vice versâ;* the solid or liquid state is evidently more dependent upon structure than upon the amount of water, blood only containing 3 per cent more water than flesh.

When flesh is very finely divided and extracted repeatedly with cold water, all the soluble matters are removed, and a tasteless, inodorous residue is left, which is perfectly white in every case like fish. This residue, when boiled with water, affords a tasteless and inodorous infusion which becomes gelatinous when cold, and the meat itself is shrivelled and horny. Treated with vinegar, it swells up into a substance which forms a turbid jelly with water, and acquires properties that are common to fibrin.

The infusion of flesh possesses a distinctly acid reaction. When kept at the boiling-point for some time, such a copious coagulation of the albumen occurs (with the colouring matter of the blood), in the form of brownish-red flocks, that the whole acquires a thick consistence. The portion that does not coagulate contains *lactic acid,* and another nitrogenous acid, *inosinic acid* ($C_{10}N_4H_{12}O_{10}$), requiring further investigation; both these acids, together with the phosphoric, are in such proportions, that they form acid salts with the bases, and thus give rise to the acid reaction of the juice of flesh. A peculiar substance, forming white crystals, and which possesses neither acid nor basic properties, is also present in this liquid. It was first discovered by Chevreul, and called by him *Creatin* (from κρεας, flesh). It has since been more accurately examined by Liebig, who found it composed of $C_8N_6H_{18}O_4+2$ aq. Powerful acids convert this substance, with the separation of water, into an organic base,*

* *i. e.* a body belonging to the same class, as quinine, morphine, &c.

Creatinine = $C_8 N_6 H_{14} O_2$, which however is also contained in the juice of flesh, without having resulted from the process of coagulation, and must consequently be considered, like creatin, as a constituent of unchanged flesh. Creatin is soluble in 74.4 parts of cold water (16°—18° C. = 61°—64° F.); Creatinine requires 11.5 parts. The former is scarcely soluble in alcohol, the latter only with difficulty. The aqueous solution of creatin possesses a slightly bitter taste, and produces an irritating sensation in the throat. According to Liebig, creatin is contained in all flesh, in that of the carnivorous and herbivorous animals, as well as in that of birds; the quantity varied, and was the greatest in the different animals in the following order: fowl, horse, deer, stag, hare, ox, sheep, pig, calf, and lastly, fish. In the same animal, the amount of creatin is obviously in proportion to its state of leanness, and diminishes with the increase of fat; whence it is obvious that it pertains exclusively to the muscular flesh. Liebig estimated it

	In raw meat.		In dried meat.	
	p. 1000.	Grains in lbs.	p. 1000.	Grains in lbs.
In the horse at	0.72	5.5	3.1	24
„ fowl „	3.06	23.5	12.2	94
„ ox „	0.69	6.4	2.8	21.5

It thus appears that the flesh of the fowl contains nearly 5 times as much as that of the ox.

Gregory found the following quantities of creatine in different kinds of flesh:

100 parts of the flesh of

Fowl yielded creatine	No. 1	3.21
	„ 2	2.90
Ox heart „	„ 1	1.375
	„ 2	1.418
Pigeon „		0.825
Skate „	„ 1	0.607
	„ 2	0.050
Cod „	„ 1	0.935
	„ 2	1.741
Goose „		0.895
Haddock „		0.614
Brill „		0.7
Herring „		1.324

In addition to these substances, there is also a nitrogenous organic acid, a substance that, in evaporating the juice of flesh, forms a pellicle on the surface of the liquid, like casein, but is distinct from it in other respects, with several others, which are only slightly known, and as yet scarcely examined. Lastly, there are several salts among which are chloride of potassium, lactate of potash, and some phosphates, of which that of lime is in the least quantity, the magnesia salt being rather more abundant, and a much larger proportion of the phosphates of the alkalies. Potash preponderates over the other fixed alkali in the juice of flesh, so that in the flesh of the ox there is 3 times, in that of the fowl 4 times, and in that of the pike 5 times, as much potash as soda. In countries that are not situated in the neighbourhood of the sea, the food derived from plants contains very little soda, and nearly all the alkali is potash. This fact is in accordance with the composition of flesh, but not with that of blood, and is one of the chief reasons which compel us to consume so much common salt, for this salt is partially decomposed by phosphate of potash into chloride of potassium and phosphate of soda. The phosphoric acid in flesh is not confined to one modification, but occurs both in the bi- and tri-basic forms.

The juice of flesh gradually becomes brown on evaporation, even at a temperature of 50° C. (122° F.), and acquires an agreeable taste of roast meat, which cannot be ascribed with certainty to any one of the known ingredients.

Preparation of meat. — In domestic arrangements, meat is cooked in three different ways. It is either *roasted, boiled,* or *steamed;* all of which produce an essential change in the chemical constitution of the flesh. In boiling meat, the water, assisted by heat, has a tendency to share the soluble matter with the juices of the flesh, or to exhaust the meat of its soluble ingredients. These consist not only of creatin, creatinine, salts, albumen, lactic acid, &c., but also of the cellular tissue and similar substances, which are converted into jelly or glue, under the influence of boiling water. Flesh would soon be separated into these constituents, if the albumen it contains did not speedily prevent this taking place, for as soon as the albumen coagulates, which occurs at a temperature of 60° C. (140° F.), it closes the interstices through which the juice from the interior would communicate with the water on the outside. From that moment the coating of albumen prevents the passage of all water from without, and the heat

only penetrates to the interior of the meat, where it produces that state of meat, known by the appellation *well done*, and, if properly regulated, the whole of the soluble portion remains with the fibre, and the meat is juicy. The exhausting action is not, therefore, of long duration, and only penetrates to an insignificant depth, thus however producing gravy, or juice which separates from the cooked meat. If the full nourishing properties are to be retained by the meat, and its power of reproducing blood and flesh is to remain unimpaired, no single ingredient can of course be removed. Neither the juice nor the boiled meat are alone sufficient for food, and it is only when both are consumed together, that the full benefit is reaped. It is further obvious, that cooked meat, eaten without the juice, is less nourishing in proportion to the amount of water added to it, and to the length of time it has been boiled. It is not, however, the nutritive quality of the meat alone that is connected with the soluble ingredients, but likewise the smell and taste, which render the meat agreeable and savoury, and enable us to distinguish between beef and veal, and between these and game, poultry, &c. These substances enter into the soup in which the meat is boiled, and the latter becomes proportionally insipid. The flesh of an animal from which all the juice has been extracted, cannot be distinguished from that of any other animal treated in the same manner, thus, veal covered with the juice of beef, possesses the very same taste as beef itself. Chevreul boiled 1 lb. of flesh, as free from fat and bone as possible, in 3 lbs. of water for five hours, supplying the deficiency caused by evaporation, and obtained a soup, which, after the removal of the fat, contained in 1000 parts,

Water (with traces of volatile matters) . . .	988.6
Solid organic matters, dried in vacuo; viz. gelatin, albumen, creatin, &c.	12.7
Potash, soda, lime, magnesia, combined with chlorine, phosphoric acid, &c.	2.9
	1004.2

and therefore a total of 1.14 per cent of soluble matter. According to the experiments of Leibig, when chopped flesh is exhausted with cold water, there are dissolved from 1000 parts of

beef, 60 parts, of which 29.5 coagulate as albumen, and 30.5 remain in solution.
fowl, 80 „ 47.0 „ „ 33.0 „

Under the most favourable circumstances, therefore, water will extract 3 per cent from beef, which quantity is increased by the gelatin (with about 2 per cent of fat) into which the membranes, sinews, &c. of the meat are transformed. 1000 parts of exhausted beef yield 6, of veal 47½ parts of dry gelatin with other soluble matters; not more therefore than $\frac{1}{5}$th of the quantity yielded by the juice.

In the kitchen it is usual to skim off the grey matter, or albumen, as it coagulates and comes to the surface of the water, thus diminishing by so much the nutritious power of the meat.

The fact that beef loses in boiling 15, mutton 10, fowl 13½ per cent of its weight, appears at first sight in palpable contradiction to the statement that the juice contains so small a portion of soluble matter. The contradiction is easily explained by the meat losing water, but gaining none during boiling. The agreeable taste of soup is sensibly augmented by the addition of acids (lactic or citric acid), or salt, while alkaline liquids render it very insipid. The reviving and strengthening quality of soup, although it contains a variety of nourishing matters, is a remarkable fact, when we remember in how small a proportion they are present.

It is not very long since it was hastily concluded that the energetic action of soup was due to the amount of gelatin it contained. Independently of the fact that the quantity of gelatin contained in soup is very small, it is known by experiment, that gelatin alone is not so capable of supporting life in an animal as gluten. When given alone as food for a considerable time, instinct revolts against it, and an insuperable loathing is produced. Nevertheless the rash conclusion was practically acted upon for a length of time, particularly in France, where the patients in hospitals were drugged with gelatin soup. The idea having once been seized, richer sources of gelatin were soon found in bones, by boiling which in closed vessels at a high temperature, and with high pressure steam, large quantities were extracted with a considerable amount of fat. On the large scale 28 per cent of gelatin (dry) and 7½ per cent of fat were extracted from bones, leaving 64½ per cent of residue. A gelatin soup of this kind, which was always spiced before it was consumed, is essentially different from soup or the juice of flesh, being of a less varied nature, and consequently not so nutritious. In the single hospital St. Louis at Paris, in nine years (1829—1839), 1,373,982 litres of bone soup were consumed in rations of

½ litre each—such a ration containing about ½ an ounce of gelatin. If gelatin or the juice of flesh is evaporated to dryness, an extract is left, of which, in the case of the latter, ⅘ are soluble in alcohol, and contains creatin and creatinine, while in the case of the former none of these substances are present, and only a very small percentage is soluble in alcohol. The two are thus easily distinguished from each other. The so-called bouillon cakes are the dried extract from the soup, and consequently as little nutritious as the soup itself.

Gelatin can therefore no longer be considered as the true cause of the remarkable qualities of soup, and it appears very probable that these are due to the creatin and creatinine which it contains, inasmuch as these belong to a class of nitrogenous substances which all exert a very energetic and even in small quantities very perceptible (often poisonous) action upon the system. Direct experiments are however requisite to prove this point. The deleterious effects of the excessive use of gelatin soup has, however, long since been directly proved by experience.

The rules for practical cookery may be deduced from the foregoing principles, and, in the first place, it appears clearly established that the practice of boiling, which yields the best soup leaves the meat in the driest and most insipid condition. The converse is also the case, so that when excellent soup is required, good meat at the same time cannot be obtained. Soup of this kind can only be obtained by slowly heating very finely chopped flesh, free from bone, with equal parts of water, to the boiling point, and allowing it to boil for some minutes. The boiling temperature coagulates the albumen, and the fibre becomes tough and hard, the soup is then strained out by pressure through a cloth. Soup thus prepared and flavoured with the ordinary additions is not different in taste from ordinary soup, but it is less deeply coloured. If the meat is left longer in contact with the water at the boiling temperature, or the soup is allowed to evaporate, it soon acquires a brown colour and the flavour of roasted meat. Evaporated to dryness, at a lower temperature, this soup affords an extract of meat which is one of the most nutritious forms of food, and is in fact what the bouillon cakes ought to be. This extract of meat, with 32 parts of water and some salt, produces a strong and agreeable soup, which can be preserved for a long time and occupies very little space, and may become at some future time, as far as its high price will admit, a most important object for dietetics and for

provisioning ships, &c. 1 lb of the extract of flesh can be obtained from 32 lbs of lean beef.

On the contrary, the opposite method must be pursued in order to render the meat savoury, tender, and nutritious. The meat should be placed in the vessel after the water has attained the boiling temperature and allowed to boil for a few minutes, the pores of the external layers then become stopped by the coagulation of the albumen, and all that is further necessary is to allow the heat to penetrate and cook the meat in its own juice. A boiling temperature which renders the fibrous portion hard is not required for this purpose, and the water should therefore be allowed to cool to about 70° C. (158° F.), and kept for some time at this temperature with the meat on the fire. The fibre becomes hard in proportion as the albumen, with which it is naturally surrounded, is separated from it, either before or during boiling. Boiling for a length of time is not calculated to produce tender meat, but if much fat covers the meat it is less affected by the heat. Of the salts contained in meat, the phosphates of the earths remain almost entirely in the meat, while the alkaline phosphates with the lactates and inosinates pass into the soup. If calcareous water is employed for cooking, the phosphoric acid is again precipitated, and to some extent, upon the surface of the meat.

The process of roasting consists in the application of heat, by means of fat, or directly, and not through the medium of water. The object is to produce tender meat and no soup. On the continent, the process of roasting is generally carried out in covered pans, the heat being applied from below and communicated to the upper parts of the meat by hot fat until the whole is well done. In this country, as celebrated for roast meat as the continent is for soup, the operation is performed by the radiant heat from a coal fire, opposite which the meat is suspended on a roasting spit, a tinned reflector concentrates the rays, while the fat and dripping juice are collected in a pan placed underneath. The heat is safely regulated by removing the meat to a lesser or greater distance from the fire.

Under these circumstances a skin very quickly forms round the meat, which is rendered denser and more impenetrable as the roasting proceeds, and so retains the juice much more effectually in the meat.

The external heat cannot penetrate thoroughly into the interior

of large joints of meat, even after protracted roasting or boiling, as is proved by the juiciness and red colour of the meat, which could not be preserved at a temperature of 70° C. (148° F.) This explains the reason why large pieces of meat are better and more tender than smaller ones, their size protects them from being overdone, which it is difficult to avoid in the other case. Small pieces can only be roasted so as to retain their juice by a quick and short immersion in very hot fat. The process of steaming meat is an intermediate method of treatment between roasting and boiling, the meat being cooked by an atmosphere of hot steam. It is placed in the steaming vessel with a very small quantity of water.

The loss of weight in roasting meat amounts in beef to 19, in mutton to 24, in lamb to 22, in fowl to 24 per cent.

CORN.

The cultivation of corn has always formed the starting point in the civilization of nations. Such culture implies the existence of fixed places of abode, and the exchange of a nomadic life for one of fixed residence must necessarily be preceded by agriculture, as the fruits of agriculture are alone capable of affording subsistence to man in one and the same spot. The mythology of the ancients, which combined the discoverer of agriculture and the dispenser of civilization in one being, points clearly to this great truth. The practical side of this truth cannot be more clearly or pointedly expressed than in the pithy words of a North American chief, which have been recorded by the French traveller Crevecour. The chief, in exhorting his people, the tribe of the Missisais, said: "Do you not see the whites living upon seeds, while we eat flesh? That the flesh requires more than thirty moons to grow up, and is then often scarce? That each of the wonderful seeds they sow in the earth returns them one hundredfold? That the flesh on which we subsist has four legs to escape from us, while we can use but two to pursue and capture it? That the grains remain where the whites sow them and grow? That winter, which with us is the time for laborious hunting, to them is a period of rest? For these reasons have they so many children and live longer than we do. I say, therefore, unto every one that will hear me, that before the cedars of our village shall have died down with age, and the maple-trees of the valley shall have ceased to give us sugar, the race of the little corn-sowers will have exterminated the race of

the flesh-eaters, provided their huntsmen do not resolve to become sowers."

Of all the material interests there is none which so completely and so tyrannically fetters the individual as the care for his daily bread. Here, neither fashion, custom, nor the power of governments can change anything, all is a pure necessity of nature. The importance of agriculture is very great, because its products are indispensable, at least amongst civilized people, governing and giving limits, in a material point of view, to the social state of mankind. No other branch of industry, not even the most extensive, can vie with agriculture; none can be compared with it, either in extent or importance; all members of society, from the highest to the lowest, without exception, constitute the enormous market for its produce at all times. Of such paramount importance is attention to agriculture on the part of the individual, that all other occupations become subsidiary. The practical man is therefore justified in demanding from science, the clearest statement and most extensive diffusion of those truths of nature, which are at the foundation of agricultural pursuits. Unfortunately the study of the products of agriculture, the alimentary substances, is among the most difficult problems of natural science, which has scarcely risen to that elevated position of accurate observation as to hold out any very great prospect of success. This explains why our knowledge upon this subject is often deficient in certain points, which from their frequent occurrence, and the daily opportunity presented for observing them, might have induced us to expect the very reverse. We do not attach this high degree of importance to every individual product of agricultural labour, what are commonly called vegetables, for instance, but, on the other hand, it is strictly applicable to the varieties of grain and flesh. The cultivation of the cereals is as old as the oldest historical traditions. There are discoveries which are peculiar to certain people or races, but the art of cultivating corn is common to the whole race of civilized man. The object of science applied to this subject consists in the explanation of the riddle, why among all plants which are suitable to the soil, climate, &c., human instinct has always selected the cereals, and what it is that so peculiarly adapts these for human food?

It will be seen in the sequel, that the solution of this question is to be found in the principles of nutrition explained above, and meanwhile, the general fact may be stated to illustrate this

particular point, that the seeds of the cereals, of the leguminosæ, &c., with reference to the mixture of proximate constituents, exhibit a most remarkable analogy to milk. Nutrition is supported by these seeds in the same manner as by milk, and by substances quite analogous to those contained in milk; they contain the same *salts* and different non-nitrogenous and nitrogenous alimentary constituents, some of which belong to the heat-producing, and the others to the blood-producing aliments, which have been already described at pages 3 and 4.*

This observation applies of course only to the flour, and not to the husk of the grains, which is indigestible, and not nutritious. The husk, however, forms so small a portion of the grain, that it has but little influence upon the relative value of the whole.

WHEAT.

Proximate constituents.—When wheaten flour, *i. e.* the ground, internal substance of the wheat grains, is kneaded with a certain quantity of water, a soft, tough mass is produced, called *dough*. This dough, kneaded with water, or exposed to a thin stream of water allowed to trickle over it, is completely disintegrated; the soluble portion of the dough is dissolved, the granules of starch are carried mechanically away, and the portion insoluble in water is left. The water flows away at first as a thick, milky liquid, and the dough becomes more porous and short. Afterwards, however, at a certain period when the water becomes less turbid, the residuary portions of the dough suddenly adhere together, become tougher, and nothing more is removed by the water. The dough is better treated with water, in a cloth, in the first instance, and washed by itself when the tough condition is attained.

Gluten.—The washed residue, which is greyish-white, tough, elastic, and more like an animal than a vegetable product, is known by the name of *gluten*. In this first state, it swells up no longer in water, and is not disposed to undergo decomposition or further change. It appears to take up a portion of water in order to acquire a certain degree of extensibility, which is not afterwards increased. Gluten attaches itself to dry bodies with great

* The proximate nitrogenous constituents of the cereals are usually (with the exception of albumen) classed together under the name of *gluten*, because the mixture obtained by mechanical separation was at first supposed to be a distinct substance.

tenacity, for instance, to the sides of the vessels, to paper or linen. If the latter substances are moistened on the opposite side, or the former immersed in water, the gluten easily separates, and can thus be obtained in a pure state. Warm water exerts no greater influence upon it than cold. Boiling alcohol, on the contrary, separates the crude gluten into a soluble portion, to which the adhesive property peculiarly pertains—*vegetable gelatin*, and an insoluble residue, which is *vegetable fibre** or *fibrin*. Crude gluten, prepared in the foregoing manner, is therefore a mixture of vegetable gelatin with vegetable fibrin, with which some particles of the husk and of starch are mixed from the imperfection of the washing process. Vegetable gelatin is likewise distinguished from fibrin by its solubility in ammonia.

Oil and glutin.—The portion of the crude gluten that is soluble in alcohol deposits, according to Johnston,† a substance resembling *casein* on cooling, and on concentrating the remaining solution an adhesive mass remains containing oil and an adhesive substance *glutin*. The oil may be separated from the glutin by ether, and possesses the general properties of the fatty oils. Much of this oil, however, accompanies the starch, and in order to obtain the whole contained in the flour, it is better to treat it at once with ether. In quantity it varies from 1½ to 3 per cent in the grain, and appears connected with the mode of culture to which the grain has been subjected. Thus seven specimens of wheat yielded the following quantities of fatty oil:

1.	From the undressed soil	1.4 per cent.
2.	Dressed with guano and wood-ash . . .	1.9 „
3.	With artificial guano and wood-ash . . .	2.2 „
4.	With sulphated urine and wood-ash . . .	2.2 „
5.	„ „ „ and sulphate of soda .	2.0 „
6.	„ „ „ and common salt . .	2.7 „
7.	„ „ „ and nitrate of soda . .	2.3 „

There appears also to be more oil contained in the husk than in the kernel of the grain. Thus:

Fine flour gave of oil . .	1.5 per cent.
The boxings	2.36 „
The pollard or sharps . .	3.56 „
The bran	3.25 „

* Not to be confounded with woody fibre.

† Agric. Chem. p. 86.

Albumen.—It would be a great mistake to suppose that all the nitrogenous constituents of flour are contained in the gluten, for a substance in large quantities is found in the water, which, from its property of coagulating in boiling water, is named *albumen.* The fibrin preponderates as regards quantity, albumen is the smallest constituent, and vegetable gelatin is intermediate between the two.

Starch.—If the turbid, milky water, which has left the gluten, is allowed to stand at rest, a granular white deposit is speedily formed, covered by a layer of dark flocculent matter and a clear liquid. The flocks are particles of gluten that have been carried away by the water, the white granular substance is *starch.* It is well characterized by its structure exhibiting microscopic, transparent roundish grains which are not affected by cold water, but swell up into a paste in hot water; and in both states produce a violet-coloured compound, with a solution of iodine. Starch forms the major part of the corn, and consequently of its non-nitrogenous ingredients. When the albumen is separated, by boiling, from the water, in which the starch was suspended, and the water is evaporated, under certain circumstances, some *sugar* is left, and always *gum*, both of which contain no nitrogen. It was formerly generally supposed that sugar was contained in the ripe, unaltered grains of corn, but recent observations (Mitscherlich, Krocker's) have proved, that fresh seed or flour yields no sugar to lime water, simply gum, although sugar is more soluble in lime water than in pure water. The sugar is produced during the analysis, by the action of an acid (which is rapidly formed when water comes in contact with flour) upon the starch.

Ash.—When wheaten grain is incinerated, an ash remains, consisting of a mixture of numerous different mineral ingredients, which amount to about 2½ per cent of the dried, or 2 per cent of the fresh grain. The mineral ingredients are partly lodged in the husk, partly in the seed. The relative proportions in which they are contained in each is not accurately ascertained, and it is only known that the ash of the husk is essentially silecious.

Johnston has recently furnished the following analyses, showing the relative amount of ash contained in the flour-bran, &c. :*

* Agric. Chem. p. 869.

Where grown.	Ash left per cent by dry			
	Fine flour.	Boxings.	Sharps.	Bran.
Sunderland Bridge, near Durham .	1.24	4.0	5.8	6.9
Kimblesworth „ „ „ .	1.15	3.8	4.9	6.7
Houghall „ „ „ .	0.96	3.0	5.6	7.1
Plawsworth „ „ „ .	0.93	2.7	5.5	7.6
Stettin	1.1	4.5	6.2	6.9
Odessa	1.1	4.9	6.6	8.0

The ash of wheaten grain has been frequently examined, with a view to ascertain the quantity and nature of the mineral ingredients which wheat assimilates from the soil.

The following table contains the chief analytical results:

TABLE—SHOWING THE COMPOSITION OF THE ASHES OF WHEAT,

ACCORDING TO RECENT ANALYSES.

Plants, or Parts of Plants.		Ashes in 100 parts of crop as taken from ground.	Ashes in dry plants, when all the water is artificially removed.	Potash.	Soda.	Magnesia.	Lime.	Phosphoric acid.	Sulphuric acid.	Silica.	Peroxide of iron.	Chloride of sodium.	Chloride of potassium.	Locality of plant.	Analyst.	Remarks.
Wheat of Foreign Growth.	Grain, red,	..	..	21.87	15.75	9.60	1.93	49.32	0.17	..	1.96	..	..	Giessen.	Will and Fresenius.	
	Grain, white,	..	..	33.84	..	13.54	3.09	49.21	..	..	0.31	..	..	Giessen.	,,	
	,,	..	..	25.90	0.44	6.27	1.92	60.39	..	3.37	1.33	..	..	Leipsic.	Schmidt.	
	,,	..	..	6.43	27.79	12.98	3.91	46.14	0.27	0.42	0.50	..	..	Holland.	Bichon.	This wheat being grown near the sea, part of the potash is substituted by soda.
	,,	..	..	24.17	10.34	13.57	3.01	45.53	..	1.91	0.52	..	..	Solz. Hesse-Cassel.	Thon.	
	,,	..	..	30.12	..	16.26	3.00	48.30	1.01	1.31	..	..	..	Bechelbronn, Alsace.	Boussingault.	
	,,	1.55	1.74	32.39	2.32	13.94	3.47	43.47	0.35	3.05	0.97	..	..	France.	Way and Ogsden.	
	,,	1.50	1.68	30.30	1.00	14.28	3.17	45.80	..	4.48	0.89	..	..	Odessa.	,,	
	,,	1.7	1.88	35.77	9.06	14.09	2.05	34.44	0.24	4.00	..	..	..	Adrianople.	,,	
	,,	1.97	2.19	36.60	0.53	11.12	4.34	41.03	0.18	4.97	1.18	..	..	Egypt.	,,	
Hopetoun Wheat, grown in England.	,,	1.81	2.05	33.15	..	12.71	3.20	47.00	0.24	2.84	0.60	..	..	Cirencester.	,,	Grown on calcareous stone-brash on the oolite.
	,,	1.51	1.69	33.00	2.07	13.99	2.82	46.18	0.48	1.42	..	..	..	,,	,,	Grown on calcareous brash and clay.
	,,	1.48	1.70	27.06	4.08	13.57	4.29	41.22	1.91	5.91	1.36	..	..	,,	,,	The seed from which the two previous specimens were grown.
	,,	1.56	1.72	32.24	4.06	10.94	2.06	45.73	0.32	2.28	2.04	0.27	..	Dorset.	,,	Loamy soil, on the clay below the chalk.
	,,	1.63	1.84	29.92	6.08	12.43	1.83	45.30	0.59	4.43	1.76	0.64	..	,,	,,	Calcareous soil.
	,,	1.61	1.81	36.43	4.62	13.26	1.32	39.97	0.15	4.23	..	..	..	Gloucestershire.	,,	Siliceous soil lying on limestone.
	,,	1.63	1.81	32.05	3.38	9.32	4.43	47.33	..	3.05	0.35	..	..	,,	,,	Clayey soil on the Silurian rocks.
	,,	1.71	1.94	34.51	1.87	11.69	1.80	43.98	0.21	5.63	0.29	..	..	,,	,,	Sandy soil on the Silurian rocks.
	,,	1.69	1.92	30.32	0.07	12.38	2.51	49.22	0.18	3.60	0.08	1.60	..	,,	,,	Clayey soil on the Silurian rocks.
	,,	1.76	2.01	32.14	2.14	9.67	8.21	44.44	..	3.29	0.08	..	..	,,	,,	Sandy soil on old red sandstone.
Red-straw White Wheat, grown in England.	,,	1.70	1.91	31.00	2.54	9.53	1.45	40.91	0.08	9.71	3.34	0.34	..	Sutton Waldron.	,,	Loamy soil on the green-sand.
	,,	1.72	1.95	29.75	0.64	13.75	3.27	49.58	0.60	2.14	0.23	..	..	Gloucestershire.	,,	Sandy loam on the old red sandstone.
	,,	1.73	1.97	29.91	1.87	14.05	3.39	47.44	..	2.63	0.67	..	..	,,	,,	Ditto. Ditto.
	,,	1.61	1.81	30.13	1.25	11.46	6.87	47.38	0.07	2.76	0.07	..	..	,,	,,	Calcareous soil on the mountain limestone.
	,,	1.60	1.80	30.02	3.82	13.39	1.15	46.79	..	3.89	0.91	..	..	,,	,,	Clayey loam on Ludlow rock.(?)
	,,	1.90	2.13	29.17	2.20	14.22	5.05	46.61	0.44	2.17	0.09	..	..	,,	,,	Sandy calcareous soil—Silurian.
	,,	1.73	1.96	26.70	2.12	12.76	6.78	46.99	0.24	2.05	2.32	..	..	,,	,,	Calcareous clay on Magnesian limestone.
Old red Lammas Wheat		1.84	2.10	34.26	4.53	9.56	3.21	40.57	0.32	5.46	2.06	..	..	Wantage	,,	Very calcareous soil on the chalk.
Spalding Wheat		1.81	2.05	29.76	5.26	11.06	2.88	48.21	0.11	2.23	0.23	..	..	Cirencester.	,,	Calcareous stone-brash; great oolite.
Creeping Wheat		1.73	1.95	31.18	2.42	12.35	1.50	46.49	0.61	5.20	0.22	..	..	Hackness.	,,	Soil, clayey sand.
,,		1.65	1.85	28.89	1.40	13.06	6.76	45.64	1.55	2.55	0.11	..	..	,,	,,	Ditto.
,,		1.71	1.91	30.94	1.28	12.74	3.72	48.53	..	1.34	1.40	..	..	,,	,,	Soil, calcareous rubble, Oxford clay.
Mean of the 32 Analyses		1.67	1.93	29.97	3.90	12.30	3.40	46.00	0.33	3.35	0.79	0.09	..			

The apparent irregularity in the mixture contained in the ash is explained by the remarkable laws developed in Vol. I. pp. 302—311; according to which, the active value of the total amount of bases must remain approximately the same, whatever modifications in the mixture may be introduced by the different character of the soil. This active value* is relatively, in the first, second, and fourth analyses, as the numbers 12.35, 11.93, 14.2.

The interesting question, also, as to what relative proportion is observed between the bases found in the ash and the other constituents of the seed, in what manner they are distributed among the fixed acids, and amongst the other vegetable substances, cannot be answered in the present state of science, as these proportions are inevitably destroyed by the process of combustion which necessarily precedes the chemical analysis. The salts are in no case contained in the seed in the state shown by the analysis, as the incineration causes numerous decompositions and changes: thus, for instance, at the temperature required, muriatic and sulphuric acids are expelled by the phosphoric; the vegetable bodies with which a portion of the bases were in combination are destroyed by the heat, and a product of their decomposition, carbonic acid, is found in combination with them in the ash.

The rather unpropitious chemical reactions of vegetable fibrin, gelatin, albumen, and gum, renders it impossible to make the quantitative estimation of these substances with the same degree of precision, as is observed with inorganic matters. Most of the investigations respecting them were also undertaken at a time when little was known of their real nature, and the analysis was confined to a mechanical separation of the gluten from the starch; nevertheless, they afford some interesting information upon some points; the experiments of Hermbstädt, for instance, on the influence of manure upon the chemical constitution of wheat, led to the following inference: he found in 10,000 parts of wheat,

Manured with	Human urine.	Ox blood.	Human excrement.	Goats' dung.	Sheep's dung.	Horse dung.	Pigeons' dung.	Cow dung.	Vegetable mould.	Unmanured.
Gluten and albumen . .	3670	3608	3554	3444	3420	1540	1412	1386	1150	1108
Starch, gum, sugar, and fat	4398	4592	4574	4652	4676	6604	6698	6726	7080	7146
Increase in grain . . .	12 fold	14 f.	14 f.	12 f.	12 f.	10 f.	9 f.	7 f.	5 f.	3 f.

* Calculated from the amount of oxygen in the bases not in combination with sulphuric or silicic acids.

As a general result, therefore, the manures that are rich in nitrogen and phosphoric acid produce wheat abounding in gluten. The relative amount of moisture and of husk does not appear affected. The kind of manure applied to wheat does sometimes influence the relative amounts of bran and flour obtained on grinding, as in five experiments, where the seed was differently manured, from 54¾ to 76½ lbs. of fine flour were obtained from 100 of wheat. The variety of the seed also appears to affect these relative quantities, although in a less degree. The lowest line of figures would also appear to indicate, that, as a general rule, the amount of produce increased with the percentage of gluten.

A valuable series of results upon this point by Mr. Burnet, of Gadgirth, are published in Johnston's Agric. Chem. p. 875. They are as follows:

Kind of manure.	Produce per acre in bushels.	Fine flour per cent from the grain.	Gluten per cent in the flour.
Unmanured	31½	76⅔	9.4
Sulphated urine and wood ashes	40	66½	10.5
,, ,, sulphate of soda	49	63⅓	9.7
,, ,, common salt	49	65⅔	9.6
,, ,, nitrate of soda	48½	54⅔	10.0

A slight increase is here perceptible with different manures, but by no means so striking as in the experiments of Hermbstädt, in which the gluten is probably over-estimated.

Chemical composition.—According to the researches of older chemists, the amount of gluten (obtained by washing) varies from 8 to 24 per cent, the starch, from 66 to 77 per cent, in wheaten grain, from different places. Payen found the gluten to vary, in four varieties of wheat, from 9 to 22 per cent, and, what is of interest with reference to the bran, a diminution of gluten towards the internal part of the seed; so that the portion of the flour which remains attached to the husk or in the bran, is richest in gluten. Analogous results were obtained by Fürstenberg in wheat-bran, who found it to contain, in 100 parts:

Gluten	10.84	Organic matter	43.98
Albumen	1.64 = 12·84	Chloride of potassium	0.23
Starch	22.62	Sulphate of potash	0.24
Gum	5.28 = 30·72	Phosphate of magnesia	0.93
Fat	2.82	Carbonate of lime	0.37
Water	10.30	Silica	0.75
Flour = 53.50 per cent.		Husk = 46.50 p.ct.	

If it were possible to separate perfectly the floury portion from the husk in the bran, we should obtain a flour containing 30 per cent of gluten and albumen; *i. e.* $\frac{3}{5}$ to $\frac{1}{2}$ times more than is contained in ordinary flour. It follows from this, that, in the present system of grinding, the most nutritious portion of the grain is not contained in the flour. The husk in good wheat amounts, on an average, to 14 or 16 per cent of the entire weight, though the quantity separated at the mill is often not more than $\frac{1}{9}$th, or 11 per cent. In making the fine white flour for the metropolis and other large towns, about $\frac{1}{8}$th of the whole is separated in the form of pollard and bran.

The average composition of bran is represented as follows by Johnston:

Water	13.1
Albumen (coagulated)	19.3
Oil	4.7
Husk and a little starch	55.6
Saline matter (ash)	7.3
	100.

It has been stated above, that the constituents of gluten and albumen are composed of the same elements, carbon, hydrogen, nitrogen, and oxygen, in the same relative proportions; the same is the case with starch, sugar, gum, and woody fibre. This point being settled, the relative amounts of nitrogenous and non-nitrogenous constituents are more accurately estimated, by calculation, from the results of an elementary analysis. The following results were obtained in this manner, in which the amount of starch was separately estimated, by converting it into sugar, and subjecting it to fermentation. The amount of carbonic acid which is then evolved, supplies data for estimating the original amount of starch (Horsford, Krocker).

	Dried at 100° C. (212° F.)						
	Wheat from Hohenheim.*			Triticum monococceum from Giessen.	Wheat from Vienna.		
	Talavera.	Whittington.	Sandomierz.		No. 1.	No. 2.	No. 3.
Gluten and albumen . .	16.52	17.09	17.15	13.20	19.15	13.53	21.93
Starch . . .	56.25	52.45	53.37	54.63	65.68	67.17	57.45
Woody fibre, gum, sugar .	24.53	26.53	25.52	29.89	14.09	18.20	20.58
Ash	2.80	3.13	2.40	2.01	0.70	0.66	1.11
	100.10	98.80	98.44	99.73	99.62	99.56	101.07
Moisture in the fresh grain .	p.cent. 15.43	p. cent. 13.93	p. cent. 15.48	per cent. 14.40	p.cent. 13.83	p.cent. 13.65	p.cent. 12.73

Boussingault examined twenty-four species of wheat upon the same principle; he found the amount of gluten and albumen of the flour to lie between 18.2 and 26.5, in mean therefore 21.7 per cent. The relation between the bran and the flour varied between 13.2 : 86.8 and 38.5 : 61.5, and was in mean as 21.3 : 78.7 to which the greater number of the specimens very nearly approached.

* These experiments agree very well with those of Fuss, as far as relates to the analyses made by the previous method.

THE FOLLOWING ANALYSES OF WHEAT HAVE RECENTLY BEEN MADE BY PELIGOT.*

	No. 1. White Flemish wheat. 1841.	No. 2. Hardy wheat. 1843.	No. 3. Touselle blanche from Provence. 1842.	No. 4. Odessa wheat, Poland.	No. 5. Blé Hérisson. 1842.	No. 6. Poulard roux. 1840.	No. 7 Poulard bleu conique. 1844.	No. 8. Poulard bleu conique. (Very dry year) 1846.	No. 9. Mitadin du Midi.	No. 10. Polish wheat. 1844.	No. 11. Hungarian wheat. 1845.	No. 12. Egyptian wheat.	No. 13. Spanish wheat.	No. 14. Tauga rock wheat.
Water	14.6	13.6	14.6	15.2	13.2	13.9	14.4	13.2	13.6	13.2	14.5	13.5	15.2	14.8
Fatty matters	1.0	1.1	1.3	1.5	1.2	1.0	1.0	1.2	1.1	1.5	1.1	1.1	1.8	1.9
Nitrogenous matter insoluble in water	8.3	10.5	8.1	12.7	10.0	8.7	13.8	16.7	14.4	19.8	11.8	19.1	8.9	12.2
Soluble nitrogenous matter (albumen)	2.4	2.0	1.8	1.6	1.7	1.9	1.8	1.4	1.6	1.7	1.6	1.5	1.8	1.4
Soluble non-nitrogenous matter (dextrin)	9.2	10.5	8.1	6.3	6.8	7.8	7.2	5.9	6.4	6.8	5.4	6.0	7.3	7.9
Starch	62.7	60.8	66.1	61.3	67.1	66.7	59.9	59.7	59.8	55.1	65.6	58.8	63.6	57.9
Cellulose	1.8	1.5	..	..	..	..	1.5	..	1.4	..	..	..	..	2.3
Saline matter	..	..	..	1.4	..	..	1.9	1.9	1.7	1.9	..	..	1.4	1.6

* The cellulose and ashes are to be deducted from the starch for the Nos. 3, 5, 6, 11, 12.
The cellulose is to be deducted for the Nos. 4, 8, 10, and 13.

RYE.

Influence of manure upon the crop.—Wheat has been examined much the most carefully, of all the cereals, the application of chemistry to the arts and to agriculture having been more fully developed in those countries where wheat is the staple commodity for food. This led to the great error of supplementing the imperfect knowledge we possess of the nature of rye, by assuming its analogy to wheat, notwithstanding the great dissimilarity between the two plants. Unfortunately the nature of rye, which is to the inhabitants of the eastern and northern parts of the continent, what wheat is to those of the southern and western districts, and to England, has been very imperfectly investigated, considering its great importance. The flour of rye is not white like that of wheat, but has a pretty strong greyish-brown tint,* and does not bind so firmly with water. It yields a short, much less tough dough, out of which it is impossible to separate the gluten from the starch by washing in water. The whole dough becomes suspended in water, without leaving any substance similar to that obtained from wheat. The cause of this is probably to be sought in some peculiarity of the gluten of rye, which is said to resemble the gluten of wheat. It contains very little fibrin, and on the contrary a nitrogenous substance, which Heldt has ascertained to be *vegetable gelatin.* The starch is of the same nature as that contained in other seeds.

Hermbstädt experimenting with rye in the same manner as with wheat, found in 100 parts:

Manured with	Ox-blood.	Sheep's dung.	Goats' dung.	Human urine.	Pigeons' dung.	Human excrement.	Horse dung.	Cow's dung.	Vegetable mould.	Unmanured.
Gluten and albumen . .	15.6	15.6	15.6	15.5	15.3	15.1	14.7	12.8	11.4	11.2
Starch, gum, sugar, fat .	63.0	63.1	62.7	59.2	61.5	63.1	60.8	64.8	66.0	67.3
Increase in grain . . .	14 fold	13 f.	12½ f.	13 f.	9 f.	13½ f.	11 f.	9 f.	6 f.	4 f.

Chemical constitution.—The action of the manure is here less

* This has been ascribed to the action of its rougher and more adherent husk, a considerable quantity of which accompanies the flour in grinding; this, however, is probably not the only cause.

marked, and the analytical results, from the very different character of the flour, cannot be regarded with the same degree of accuracy as in the case of wheat. The same applies to the following analyses of rye flour made by the older methods:

	Rye flour.				Rye and bran.	
	Einhof.	Greif.	Boussingault.		Fürstenberg.	
Gluten	9.48	12.8	10.5	3.96	Organic matter	6.18
Albumen	3.28	3.0		3.34	Chloride of potassium	0.01
Starch	61.07	58.8	64.0	65.32	Phosphate of magnesia	0.39
Sugar	3.28	10.4	3.0	—	Silica	0.12
Gum	11.09	7.2	11.0	3.78		
Woody fibre	6.38	—	6.0	—	Bran	6.70
			Fat.		Water	14.98
						78.32
Acid unexamined, loss	5.62	7.8	3.5	1.92		
	100.20	100.0	98.00	78.32		100.00

More accurate results may be calculated as follows from the elementary analysis of Horsford and Krocker.

	Dried at 100° C. (212° F.)					
	Rye flour from Vienna.		Rye flour from Hohenheim.		Buck-wheat flour from Vienna.	Tartarian buck-wheat from Hohenheim.
	No. 1.	No. 2.	Schilf.	Standen.		
Gluten and albumen	11.92	18.69	17.73	15.76	6.88	9.94
Starch	60.91	54.48	45.09	47.42	65.05	44.12
Woody fibre, gum, sugar.	24.74	24.49	35.77	35.25	26.47	46.26
Ash	1.33	1.07	2.43	2.37	1.09	2.30
	98.90	98.73	101.02	100.80	99.49	102.62
Moisture in fresh substance	13.78	14.68	13.94	13.82	15.12	14.19

Dombaste found that 100 parts of rye-flour yielded, when baked, 145 of bread, or nearly the same quantity as is yielded by wheaten flour. Johnston found rye bread, when leavened, to lose 44, when yeasted, 46 per cent of water. One hundred pounds of flour containing naturally 16 per cent of water, must then have yielded from 150 to 160 lbs. of bread.

The ash of dry rye consists, according to Will, Fresenius and Bichon, of:

	Rye		Buck-wheat
	From Giessen.	From Cleves.	from Cleves.
Potash	31.89	11.43	8.74
Soda	4.33	18.89	20.10
Lime	2.84	7.05	6.66
Magnesia . . .	9.86	10.57	10.38
Oxide of iron . .	0·80	1.90	1.05
Phosphoric acid .	46.03	57.81	50.07
Common salt . .	trace	—	—
Silica	1.42	0.69	0.69
Sulphuric acid .	0.17	0.51	2.16
Charcoal, sand, &c.	2.66	—	—

Way and Ogsden found in a specimen of rye from Kidderminster 1.36 per cent of ash in the plant as taken from the field, and 1.60 in the artificially dried grain, the composition of the ash was as follows:

Potash	33.83
Soda	0.39
Magnesia	12.81
Lime	2.61
Phosphoric acid . .	39.92
Sulphuric acid . . .	0.17
Silica	9.22
Peroxide of iron . . .	1.04
	99.99

Practical agriculturists, who long since introduced buck-wheat to the growers of corn, find a sanction for this practice in the identity in composition of buck-wheat and rye. In the seeds of the former there is 27 per cent of husk. The 73 per cent of flour—closely resembling that of rye in colour and properties—contain 10½ of gluten, and 52 of ordinary starch. The greatest resemblance also exists in the constitution of the ash, when both plants have been grown upon the same soil, as is obvious from the above analyses.

The dried grains of rye contained 2.4 per cent, those of buck-wheat 2.1 per cent of ash.

BARLEY AND OATS.

Chemical composition.—The fresh grain of barley and oats was found to consist of:

	Water.	Bran.	Flour.	
Oats	—	34	66	Vogel.
Oats	21	17	62	Boussingault.
Common barley	11	19	70	Einhof.
Naked barley	10	17	73	" "
Barley	13	18	69	Boussingault.

The mean of 8 samples of Scotch oats gave Mr. Norton:*

Grain . . 76.28 } The maximum of husk being 28.2,
Husk . . 23.68 } and the minimum 22.0.

The composition of the husk as ascertained by the same observer was in two specimens as follows:

	Hopeton oat.	Potato oat.
Oil	1.50	0.92
Sugar and gum	0.47	0.75
Gluten and coagulated albumen	1.88	1.88
Cellulose	89.68	89.46
Saline matter (ash)	6.47	6.99
	100.	100.

Barley and oats have been less perfectly examined than any of the other corn fruits, and the nature of the gluten contained in them is totally unknown. All that can be said with certainty upon that point, is confined to the observation that the gluten of these two grains is mechanically separated with much greater difficulty than that of either wheat or rye, that by the agency of some other substance in the flour, it is almost wholly dissolved in water, and is much less abundant than in either of the other two. It is also probable that it contains but little fibrin, and resembles in this respect the gluten of rye. From these causes, the analyses, consisting in the separation of the constituents of the flour which are hardly known even superficially, can be of no value in themselves, and are only of interest for the sake of comparison when, like those

* Johnston's Agric. Chem. p. 885.

of Hermbstädt, they are carried out in a precisely similar manner. Hermbstädt found in 10,000 parts:

BARLEY.

Manured with.	Ox blood.	Human excrement.	Sheep's dung.	Goats' dung.	Human urine.	Horse dung.	Pigeons' dung.	Cow dung.	Vegetable mould.	Unmanured.
Gluten and albumen .	616	622	616	352	636	610	646	612	310	308
Starch, gum, sugar & fat.	6944	6948	6932	7162	6906	6944	?	6932	7210	7232
Increase of grain . .	16 fold.	13 fold.	16 fold.	15 fold.	13⅓ fold.	13 fold.	10 fold.	11 fold.	7 fold.	4 fold.

OATS.

Gluten and albumen .	54	50	45	47	49	45	35	33	22	21
Starch, gum, sugar & fat.	6270	6280	6500	6460	6420	6560	6530	6940	7350	7370
Increase of grain . .	12⅓ fold.	14⅓ fold.	14 fold.	15 fold.	13 fold.	14 fold.	12 fold.	16 fold.	13 fold.	5 fold.

The action of the manure, therefore, tends on the whole more to increase the crop than to the production of gluten; in the case of oats the weight of the husk was increased by animal manure, while in the case of barley no difference was perceptible, nor was the amount of moisture in either affected.

According to Proust the greater part of the non-nitrogenous constituent in barley is not starch, although a substance similar to it, but insoluble in boiling water, which he called *hordein*.

The composition of the French oat including the husk is, according to Boussingault,* as follows. By drying at 230° F. it lost 20.8 per cent of water, and then contained of:

Starch	46.1
Glutin-avenin,† albumen . . .	13.7
Oil	6.7
Sugar	6.0
Gum	3.8
Husk-ash, and loss	23.7
	100.

* Rural Economy, in its relations with Chemistry, Physics, and Meteorology. Second edition, with Notes, London, 1845, p. 228.

† A substance resembling casein, precipitated by acetic acid from the aqueous solution of oatmeal.

Four varieties of Scotch oats examined by Messrs. Norton and Fromberg gave, exclusive of husk:

	Hopeton oats, Northumberland.	Hopeton oats, Ayrshire.	Hopeton oats, Ayrshire.	Potato oats, Northumberland.
Starch	65.24	64.80	64.79	65.60
Sugar	4.51	2.58	2.09	0.80
Gum	2.10	2.41	2.12	2.28
Oil	5.44	6.97	6.41	7.38
Avenin (Protein compounds)	15.76	16.26	17.72	16.29
Albumen (Protein compounds)	0.46	1.29	1.76	2.17
Glutin (Protein compounds)	2.47	1.46	1.33	1.45
Epidermis	1.18	2.39	2.84	2.28
Alkaline salts, and loss	2.84	1.84	0.94	1.75
	100. N.	100. F.	100. F.	100. N.

From these analyses it appears that the oat is very rich in oily matters and protein compounds.

The proportions of nitrogen and protein compounds in nine specimens of oats have been determined by Norton as follows:

	Hopeton oats.			Potato oats.		Oats from Barnbarroch, Wigtonshire.			Imperial oats, New York, U.S.
Nitrogen	2.19	2.35	2.28	2.76	2.82	2.89	5.51	2.49	3.00
Protein compounds	14.0	14.78	14.04	17.36	17.77	18.24	22.01	15.66	18.86

The relative proportions of nitrogen and protein compounds in the husk, grain, and whole oat, were as follows:

	Husk.	Grain.	Whole oat.
Nitrogen	0.30	2.82	2.18
Protein compounds	1.88	17.77	13.72

The results deduced from elementary analysis are strangely contradictory to the older examinations, which state that barley contains at most 6, and under 3 per cent gluten and albumen, and oats from 6 to 3 per cent.

	Dried at 100° C. (212° F.)				
	Krocker and Horsford.		Krocker and Horsford.		Thomson.
	Winter barley. Hohenheim.	Jerusalem barley. Hohenheim.	Kamschatka oats. Hohenheim.	White ? oats Hohenheim.	Barley. Scotland.
Gluten and albumen	17.70	14.72	17.99	12.17	15.24
Starch	38.31	42.34	37.41	} 84.74	39.86
Husk, gum, sugar	42.33	42.46	45.67		46.19
Ash	5.52	2.84	4.14	3.09	3.26
Moisture in the first grain	13.80	16.79	12.94	9.46	12.71

The proportion of gluten and albumen is in reality still greater, as the husk in these grains on account of their thin, pointed shape, is more abundant, particularly in the oat (17 per cent), than in the foregoing (excepting only buck-wheat in which there is 22 per cent).

The value of barley depends much upon the relative hardness of its husk, and this appears to be influenced by soil and manure in its culture. A soft thin skin adapts it better for malting, and a light chalk soil is best suited to produce it of this character. Fromberg has ascertained that the hard barley contains less gluten and albumen than the softer kinds, thus he found:

	Water.	Nitrogen equal to gluten, &c.
Soft or malting barley to contain per cent	13.55	10.93
Flinty or pot barley	13.4	8.03

The ash of barley is constituted as follows:

TABLE—SHOWING THE COMPOSITION OF THE ASHES OF BARLEY AND OATS, ACCORDING TO RECENT ANALYSES.

Plants, or Parts of Plants.	Ashes in 100 parts, in crop as taken from the ground.	Ashes in artificially dried plants.	Potash.	Soda.	Magnesia.	Lime.	Phosphoric acid.	Sulphuric acid.	Silica.	Peroxide of iron.	Chloride of sodium.	Chloride of potassium.	Locality of plant.	Analyst.	Remarks.
Barley, grain and straw, .	..	7.15	13.86	..	3.96	11.81	7.67	4.37	37.27	2.30	1.84	..	Oxford.	Daubeny.	Grown in Botanic Garden of Oxford —soil recently manured.
,, grain of, ...	2.04	..	19.1	..	7.6	3.6	31.2	3.4	33.2	2.30	2.3	..	Ensham.	,,	Soil on Oxford clay.
,, grain, ...	2.37	..	3.91	16.79	10.05	3.36	40.63	0.26	21.99	1.93	..	..	Cleves.	Bichon.	
,, grain, ...	..	..	20.91	..	6.91	1.67	38.48	..	29.10	2.10	..	..	Leipsic.	Schmidt.	
,, grain, without husk	2.5	..	29.50	..	15.90	2.90	47.0	1.00	1.30	..	..	..	France.	Boussingault.	
,, grain, ...	3.05	..	16.00	8.86	4.30	3.23	36.80	0.16	29.67	0.83	..	..	Scotland.	Thomson.	
,, grain, ...	2.70	..	13.75	6.75	8.60	2.21	39.80	0.17	27.65	1.07	..	..	Neufchatel.	Köchlin.	
,, grain, (?)	1.90	..	21.1	1.3	7.2	4.5	29.7	2.4	34.0	2 44	..	..	Essex.	Daubeny.	
,, grain, ...	2.14	2.43	21.14	..	7.26	1.65	28.53	1.91	30.68	2.13	1.01	5.65	Dorset?	Way and Ogsden.	Calcareous soil.
,, grain (Chevalier), .	2.25	2.50	20.77	4.56	7.45	1.48	31.69	0.79	32.73	0.51	..	..	..	,,	
,, grain (Moldavian),	2.12	2.43	31.55	1.06	10.17	1.21	28.64	0.27	24.56	1.02	1.47	..	..	,,	
Mean of 10 *analyses of barley grain*, . . .	2.34	2.43	19.77	3.93	8.55	2.58	35.20	1.03	26.49	1.43	0.47	..			
Oats, grain, ...	..	..	12.3	..	7.7	3.7	14.9	1.0	53.3	1.3	..	1.0	Alsace.	Boussingault.	
,, ,, (Hopetoun), .	2.27	2.50	17.80	3.84	7.33	3.54	26.46	1.10	38.48	0.49	0.92	..	Dorset.	Way and Ogsden.	Calcareous soil.
,, ,, (Potato), . .	2.45	2.73	19.70	1.35	8.25	1.31	18.87	0.10	50.03	0.27	0.07	..	..	,,	
,, ,, (Poland), . .	2.65	2.97	24.30	5.51	8.26	2.65	14.49	1.74	41.86	0.69	0.45	..	..	,,	Grown from the grain of previous sample.
,, ,, (Poland), . .	3.31	3.80	16.35	5.27	5.90	8.35	16.19	4.01	43.20	0.09	..	..	..	,,	
,, ,, ...	2.75	3.12	13.97	1.50	8.82	4.22	21.53	0.13	49.44	0.36	..	..	Cirencester.	,,	
,, ,, ...	4.00	..	12.90	..	7.70	3.70	14.90	1.00	53.30	1.30	..	..	France.	Boussingault.	
,, ,, (Potato), without husk .	2.22	..	21.22	..	11.26	6.69	38.48	18.36	3.60	..	..	..	Scotland.	Norton.	
,, ,, (Hopetoun), do.	2.14	..	31.15	..	8.64	5.21	49.19	2.54	1.73	0.80	..	..	,,	,,	
Mean of 7 *analyses of oats grain* . . .	2.90	3.02	16.76	2.49	7.70	3.92	18.19	1.29	47.08	0.64	0.20	0.14			
Mean of 2 *analyses, oats without husk* . . .	2.18	..	26.18	..	9.95	5.95	43.84	10.45	2.67	0.40	..	..			
Oat husks, ...	6.49	..	6.99	..	1.01	4.31	2.65	5.01	74.73	1.61	..	..	Scotland.	Fromberg.	Grown on mossy land.
,, ...	7.22	..	5.66	..	0.64	2.05	1.80	4.90	81.72	1.80	..	..	,,	,,	
,, (Hopetoun), .	6.46	..	7.39		0.38	1.95	1.04	11.61	73.85	1.58	..	..	Northumberland.	Norton.	
,, (Potato), . .	6.99	..	12.47		2.35	4.30	0.66	4.30	74.28	0.32	..	..			
Mean of 4 *analyses of oat husks*	6.79	..	8.13		1.09	3.15	1.54	6.46	76.16	1.33	..	..			

INDIAN CORN AND RICE.

Chemical constitution.—When the dough of Indian corn is washed with water like that of wheat, a glutinous residue is left different from the gluten of wheat, and characterized by its solubility in alcohol, and therefore allied to vegetable gelatin. According to Bizio only $\frac{1}{3}$ of this gluten is insoluble in alcohol; he obtained, as did Gorham, $5\frac{1}{2}$ per cent of gluten. Elementary analysis, however, yielded:

	Indian meal from Hohenheim.	Indian meal from Polenta, Vienna.	Rice.
Gluten and albumen .	14.66	13.65	7.40
Starch . . .	66.34	77.74	86.21
Husk, sugar, gum, fat .	18.18	7.16	5.39
Ash . . .	1.92	0.86	0.36
Water in the fresh substance.	14.96	13.36	15.14

Two specimens of rice examined by d'Arcet and Payen, the one from Lombardy, and the other from Carolina, contained $13\frac{1}{2}$ of moisture, and 12 per cent of nitrogenous matter; the method, however, employed was calculated to yield too much. The seeds of Indian corn contain more fat than those of the other cereals, and as much as $4\frac{1}{2}$ per cent of a yellow thickly-fluid oil.

Millet is an article of food very similar to rice.

Johnston found a specimen of unhusked rice to consist of:

Husk . . .	20.91
Grain . . .	79.09
	100.

Five varieties of rice freed from husk gave respectively of water and ash the following proportions:

	Water.	Ash.
Madras rice . . .	13.5	0.85
Bengal rice . . .	13.1	0.45
Patna rice . . .	13.1	0.36
Carolina rice . .	13.0	0.33
Carolina rice flour . .	14.6	0.35

Payen found dry rice to contain:

Starch	86.9
Gluten, &c.	7.5
Fatty matter . . .	0.8
Sugar and gum . . .	0.5
Epidermis	3.4
Saline matter (ash) . .	0.9
	100.

Rice contains less fatty matter than any other grain, and the greater portion of the fat is contained in the outer coats. Johnston found in the siftings or cleanings of rice from 5 to 5½ per cent of fatty matter.

Maize or Indian corn yielded Payen 14 per cent of water, and the dried grain the following ingredients:

Husk	5.9
Gluten	12.3
Starch	71.2
Sugar and gum . . .	0.4
Fatty matter . . .	9.0
Saline matter or ash . .	1.2
	100.

The ashes of rice, maize, and millet, have been analysed with the following results:

	Potash.	Soda.	Magnesia.	Lime.	Phosphoric acid.	Sulphuric acid.	Silica.	Peroxide of iron.	Chloride of sodium.	Chloride of potassium.	Analyst.	Locality.
Maize grain . } Indian corn . }	26.63	7.54	15.44	1.59	39.65	5.54	2.09	0.60	..	..	Fromberg.	United States.
" " . .	30.8		17.0	1.3	50.1	..	0.8	..	..	..	Letellier.	Bechelbronn.
Mean . . .	32.48		16.22	1.44	44.87	2.77	1.44	0.30	..	..		
Rice grain . .	18.48	10.67	11.69	1.27	53.36	..	3.35	0.45	..	..	Johnston.	..
Rice husk . .	1.60	1.58	1.96	1.01	1.86	0.92	89.71	0.54	..	..	"	..
Millet grain .	9.58	1.31	7.66	0.86	18.19	0.35	59.63	0.63	1.43	..	Rölich.	Giessen.

LEGUMINOUS FRUITS.

Characters.—While starch still continues to form the preponderating ingredient in leguminous seeds, and its chemical nature and structure are identical in every respect, the nitrogenous ingre-

dient exhibits a difference which distinguishes clearly this class of fruits from the cereals. Their abundant supply of nitrogenous matter, also claims for them the highest place in the scale of nutritive aliments.

Chemical nature of their constituents.—When peas, beans, or lentils, are allowed to swell for some hours in lukewarm water, until they can be easily crushed into a paste, and this paste is washed through a fine sieve, the skins alone remain, and a milky liquid passes through. The milky liquid deposits a considerable quantity of starch after standing for some time, while the whole of the gluten-representative is retained in solution. This solution is always somewhat turbid and soon becomes acid (by the formation of lactic acid), the acidity rapidly increases, and eventually after twenty-four hours the whole is coagulated to a soft, gelatinous mass. Heated to the boiling-point before becoming acid, no coagulation occurs, as is the case with albumen, but a scum is formed on the surface which reappears as often as it is removed. Coagulation immediately follows the addition of alcohol to the solution; and acids in like manner produce a precipitate which is soluble in an excess of some of them (tartaric and oxalic acids) although not in others (sulphuric and nitric acids). The precipitates are combinations of the precipitated organic substance with the acids, and they possess an acid reaction. Ammonia and caustic potash produce no precipitate in the solution, and indeed redissolve the acid precipitates; sulphur passes in this case to the alkali, and can be again separated in the form of sulphuretted hydrogen. The organic matter thus held in solution leaves an ash upon incineration, which exhibits an alkaline reaction; the substance itself was first accurately studied by Braconnot, and distinguished by the name of *legumin*, as that ingredient of the leguminosæ which corresponds to the gluten of the cereals. Subsequent elementary analysis, and the more accurate knowledge of the casein of milk, acquired at a later period, led to the comparison of the above characteristic reactions with those peculiar to the casein of milk, and established the important fact that the two substances were chemically identical. The gluten of the leguminous fruits has, therefore, been denominated *vegetable casein*, (Liebig).

Legumin cheese.—A remarkable corroboration of this scientific discovery was furnished by the report of J. Itier, in which the following fact is stated. The Chinese prepare an actual cheese

from peas, called tao-foo, which is often sold in the streets of Canton. In preparing this cheese, the paste from steeped and ground peas is boiled, which causes the starch to dissolve with the casein. After straining the liquid it is coagulated by means of a solution of gypsum. The coagulum is worked up like acid milk, salted and pressed in moulds to form an amylaceous cheese.

Chemical constitution.—Sugar appears to be contained in only a few of the leguminosæ, as in the sugar-pea; gum, on the contrary, mucus and pectic acid, a wax-like substance, and the same salts as in grain are constant ingredients in all. In the skins, particularly of lentils, tannin is found, which forms a black precipitate with salts of iron.

The older very defective analyses yielded the following results:

	Peas.		Beans. *Phaseolus comm.*		Sow beans. *Vicia faba.*		Lentils.
	Braconnot.	Einhof.	Einhof.	Braconnot.	Einhof.	Braconnot.	Einhof.
Nitrogenous matter.	26.4	16.3	22.2	23.5	11.7	23.6	37.3
Starch . .	42.6	32.4	35.9	42.3	34 2	42.3	32.8
Skin . . .	8.3	?	7.5	7.0	10.0	7.0	18.7

The chemical constitution is very different, as deduced from the elementary analyses of Horsford and Thomson, as well as from the results of Krocker.

	Horsford and Krocker.					Thomson.
	Table pea. Vienna.	Field pea. Giessen.	Table bean. Vienna.	Large white bean. Giessen.	Lentils. Vienna.	Sow bean. Scotland.
Vegetable casein, and albumen .	28.02	29.18	28.54	29.31	30.46	29.43
Starch . .	38.81	} 66.23	37.50	} 66.17	40.00	} 66.61
Gum . . .	28.50		29.20		25.06	
Ash . . .	3.18	2.79	4.38	4.01	2.60	3.96
Skin . . .	7.65	6.11	4.11	4.41	?	?
Moisture in the fresh fruit. .	13.43	19.50	13.41	15.80	13.01	10.60

The ash is composed as follows:

	Will and Fresenius. Pea.	Bichon. Pea.	Bichon. Sow bean.	Levi.		Thomson. Sow bean.
				Bean.	Lentil.	
Potash	39.51	34.19	20.82	38.89	34.31	23.15
Soda	3.98	12.76	19.06	11.78	13.30	9.42
Lime	5.91	2.46	7.26	5.90	6.24	5.18
Magnesia	6.43	8.60	8.81	9.03	2.44	9.03
Oxide of iron	1.05	0.96	1.03	0.11	1.98	1.80
Phosphoric acid	34.50	34.57	37.94	31.34	35.82	35.26
Chloride of sodium	3.71	—	—	—	—	—
Chlorine	—	0.31	1.48	0.33	4.56	1.75
Sulphuric acid	4.91	3.56	1.34	2.47	—	1.29
Silica	—	0.25	2.46	0.44	1.31	13.12

A large quantity of alkali, and a larger proportion than usual of sulphuric acid characterize, therefore, the ashes of the leguminous seeds.

The amount of vegetable casein in these products, and the property this body possesses of being precipitated, or rendered insoluble by salts of lime, particularly by gypsum, explains at once why the leguminous seeds are not easily boiled soft in hard water.

THE POTATO.

The introduction of the potato into agriculture, must be viewed as a historical occurrence of the highest importance, the extraordinary results of which extends far beyond the actual culture of the bulb itself. The influence which it has exerted is due to two different causes: first, the peculiar power which it possesses of acclimatizing itself in all latitudes, from the Cape to Lapland; and second, the fact that by its means much more nourishment can be produced from the soil, than with any other crop. An example will prove this in a remarkable manner. From 1 hectare* of land there were produced under similar circumstances:

3400 lbs. of wheat, 2800 lbs. of rye, 2200 lbs. of peas, and 38000 lbs. of potatoes, or
3036 „ „ 2538 „ „ 2980 „ „ 9500 „ „

after deducting the amount of moisture. In this quantity of dry produce there is contained:

	In wheat.	In rye.	In peas.	In potatoes.
Nitrogenous matters	570 lbs.	440 lbs.	560 lbs.	950 lbs.
Starch	1590 „	1196 „	780 „	6840 „
Mineral ingredients	90 „	62 „	60 „	323 „

* The hectare is equal to 2.471 acres.

However much the produce in single years may differ from the instance above quoted, still a similar relation will always be observed, and the potato will yield twice as much of these three kinds of nutritive food as any other crop.

Origin.—The potato came originally from South America, where it has recently been found by Caldcleugh and Baldwin growing wild, near Monte Video, in Chili. It was probably brought to Europe before the time of Drake by Hawkins (1545), who introduced it into Ireland. About the year 1710 it began to be generally disseminated through Germany, where for a long time it was considered a rarity, until the famine in 1771—72 caused it to become an object of general culture. It is well known that the potato is not actually a fruit, but a bulbous protuberance of the root, consisting of a collection of cells, and possessing in common with fruits the property of being propagated by means of germs. The starch is stored up in these cells in the form of grains, of the ordinary shape, and these congregate principally in a zone near the skin, and are less abundant towards the centre, the remaining space in the cell is occupied by so limpid a juice, that water is found to constitute by far the largest portion, namely, three-fourths of the weight of the potato. All the nitrogenous matter is dissolved in the juice, and consists almost entirely of albumen, with a very small quantity of asparagin and free acids. Asparagin ($C_8\,N_4\,H_{16}\,O_6$) is an easily crystallizable, neutral substance, which occurs in several plants, as in the marshmallow (*Althæa*), comfrey (*Symphytum*), and in asparagus (whence it derives its name), and in crystallizing it takes up 2 equivs. of water. About $\frac{1}{1000}$ part is contained in the potato.

The acid reaction of fresh potato juice is derived from phosphoric and muriatic acids, as well as an organic acid, malic acid ($C_4\,H_2\,O_4$, Aq.) according to Illisch, and not from citric acid, as was formerly erroneously believed. The sulphuric acid which is found in the ash of the potato must have been produced during incineration from the sulphur of the albumen, for it does not occur in the juice. The expressed juice of the potato, and the yellow gratings become of a blackish-brown colour when exposed to the air, a result which must be attributed to an oxidizing process, although it is still unknown which ingredient of the juice is thus affected. It is well worthy of notice, that the substance of which the cells of the potato consist, is essentially different from that which is found in other plants. It possesses the property of swelling in water into a translucent jelly, and of being transformed

into sugar and gum by the action of acids, and consequently occupies a position intermediate between starch and woody fibre. During the germinating process of the potato, an organic base, *solanine*, is produced in perceptible quantity. It is a volatile liquid, and its composition is expressed by the formula $C_{84}\ H_{146}\ N_2\ O_{28}$. So poisonous are the properties of this body, that small quantities produce lameness (in cattle). In potatoes that have not germinated, no solanine is contained. One great advantage which the potato possesses over other fruits, is the thin substance of its skin, an advantage, however, which is counterbalanced by the large proportion of water which it contains.

Frozen potatoes.—The amount of water in the bulb, is the cause of the destruction to which potatoes are subject when exposed to frost. At a temperature a few degrees below 0° C. (32° F.) the water in the juice is frozen, the tubers become hard like wood, and afterwards when thawed, they are soft and sodden, and allow the greater part of the juice to flow out. The expansion of the water in becoming ice bursts the cells, destroys the organic structure and the vital power (power of germinating) of the tuber is lost. With this vital principle the power of resisting decay likewise vanishes, and the potatoes speedily undergo decomposition. In addition to this mechanical action of frost, a chemical change is often perceptible, particularly when the tubers are frequently frozen and again thawed; they then affect a remarkably sweet taste, and contain an appreciable quantity of uncrystallizable sugar, which appears to arise from a decomposition of the starch, at other times only produced by acids or diastase. More accurate knowledge respecting the action of frost in producing sugar is unfortunately still wanting, but no sugar is produced when the tubers are rapidly frozen. It is possible that incipient germination may be necessary to its production. Girardin and Payen have proved that no other change of the constituents as regards their relative weight, occurs when the tubers are frozen; they may consequently be employed for the usual purposes before decomposition has commenced. The property of keeping, and not the actual value has suffered.

Chemical constitution.—The chemical constitution of the potato with reference to the relative quantities of the ingredients, has been made the subject of repeated experiment. In ascertaining these relations, the mechanical separation—which is here more practicable than with other products—has been called in aid, as well as elementary analysis.

According to Einhof and Lampadius, potatoes contain between 70 and 81 per cent of water, and therefore between 30 and 19 per cent of solid matter, of which between 9 and 18 per cent is starch, and from 1 to 1½ per cent albumen. Körte found in fifty-five varieties of the potato, the mean quantity of water between 68 and 76 per cent; the fixed constituents, therefore, between 24 and 32 per cent, while the percentage of starch varied from 8 to 16.

Johnston found, as the mean result of twenty-seven analyses, the maximum quantity of water in young potatoes 82, and the maximum in full-grown potatoes 68.6 per cent. The mean of fifty-one determinations made upon potatoes of all ages was 76 per cent.

The water appears to abound most in the upper part or rose of the potato, from which the young shoots spring, and the different varieties grown under like circumstances, were found to take different quantities of water. Thus while the cup potato gave 74, the variety called buffs gave 77 per cent.

For an interesting comparison of sixty-six varieties of potatoes from Hohenheim, we have to thank Siemens. He found:

a. The amount of dry solid matter in minimum 18.66, in maximum 28.60, in mean 24.93. In 46 varieties this mean lies between 23 and 26 per cent.

b. The amount of starch varied between a minimum of 11.16, and a maximum of 19.25; the mean was therefore 15.98 per cent.

All these results were obtained by mechanical separation.

The variety affects likewise the quantity of starch. Thus Johnston obtained the following results from potatoes grown in Scotland in 1846:

	Per cent.
Red potato (Lanarkshire) . . .	14.08 of starch.
Small Americans	17.80 „ „
Orkney potatoes	17.42 „ „
Buffs (Forfarshire)	20.71 „ „
Kidneys	14.93 „ „
Cups (Argyleshire)	15.14 „ „

Mr. Heming obtained from different varieties grown on the same soil in Renfrewshire the following quantities respectively of starch:

	Per cent.
Connaught cups . . .	21
Irish blacks	16½
White dons	13
Red dons	10¾

and a starch manufacturer in that neighbourhood obtained 11½ per cent, as an average quantity from rough red potatoes of good quality.

The difference is striking when taken in connection with the relative yield per acre: thus,

	Produced per acre	Containing of starch.
Cups . .	13¼ tons.	2.9 tons.
Red dons .	14¼ „	1.5 „
White dons	18½ „	2.4 „

so that the cups, though yielding the least quantity per acre, produced the greatest quantity of starch.

Fat.—The fat extracted by ether from the dried potato amounts to between 0.51 and 0.52 per cent.

Johnston found the following average quantities of gum and sugar:

	Maximum.		Minimum.		Mean.	
	Sugar.	Gum.	Sugar.	Gum.	Sugar.	Gum.
In the natural state	5.1	0.94	1.1	0.07	3.3	0.55
In the dry state .	23.2	3.0	5.5	0.35	13.47	2.25

The gluten varies according to Johnston from 0.11 to 0.56 p. c. in the natural state.
The albumen „ „ „ „ „ 0.03 „ 0.75 „ „ „
The casein „ „ „ „ „ 0.02 „ 2.24 „ „ „

These quantities were, however, obtained separately, and if the protein compounds are estimated altogether they amount, according to Fromberg, from 7.3 to 14 per cent of the dry bulb.

By elementary analysis Horsford and Krocker found:*

* The amount of starch was found by converting it into sugar, and subsequent fermentation. The parenchyma (substance of the cell walls) however, takes part in this process, and it is, therefore, uncertain how much is due to the starch alone. Judging, however, from the foregoing determination, it appears that this admixture is not of much moment.

	Horsford and Krocker.			Schlossberger.
	White potatoes. Giessen.	Blue potatoes. Giessen.	Other varieties. Giessen.	Würtemberg potatoes.
Albumen and asparagin, &c. .	2.49	2.37	—	2.53
Starch	17.98	23.21	16.18	—
Other organic matters . .	3.60	4.18	} 7.02	—
Mineral substances (ash) . .	0.90	1.04		—
Dry matter . . .	24.97	30.80	23.20	—
Water	74.95	68.94	76.80	—

The chief cause of the great differences in the amount of starch, as is exhibited in the table, is doubtless due to the age of the tubers, for according to other observations, potatoes which were carefully preserved from germinating, from heat and frost, contained:

	Starch:		Starch:
In August	9.5 to 10.4 per cent	In November to March	15.8 to 18.7 per cent
In September	13.3 to 13.7 „	In April „ „	15.5 to 11.6 „
In October	13.3 to 16.6 „	In May „ „	11.6 to 8.32 „

The ash of the potato has the following composition:

TABLE SHOWING THE COMPOSITION OF POTATO ASH:

	Ash in 100 parts.	Ash in artificially dried plant.	Potash.	Soda.	Magnesia.	Lime.	Phosphoric acid.	Sulphuric acid.	Silica.	Peroxide of iron.	Chloride of sodium.	Chloride of potassium.	Locality of plant.	Analyst.	Remarks.
Potato tuber.	..	4.00	59.96	..	6.28	2.09	13.16	8.27	6.52	0.59	5.20	..	France.	Boussingault.	Carbonic acid deducted.
"	..	4.01	57.58	3.66	4.53	0.81	9.98	14.63	3.68	0.42	8.6	..	Lanark.	Fromberg.	"
"	..	3.75	49.73	1.93	5.03	3.31	14.58	18.04	2.49	0.56	7.5	..	Drummore.	"	"
"	1.27	..	46.60	..	8.70	4.54	13.30	4.66	1.95	3.30	3.43	..	Oxford.	Daubeny.	"
"	1.08	..	50.00	0.84	6.85	2.70	16.20	2.37	7.15	5.15	1.95	..	"	"	Carbonic acid 13.30.
"	0.76	..	43.80	..	12.65	3.10	11.15	6.0	6.67	6.85	2.30	..	"	"	" 11.90.
Mean of 6 analyses, carbonic acid being deducted	..	3.92	55.75	1.86	5.28	2.07	12.57	13.64	4.23	0.52	7.01	..			" 6.70.

The following mean composition is the result of the numerous analyses of healthy potatoes made by Professor Johnston :

	In natural state.	Dry.
Water	75.52	..
Starch	15.72	64.20
Dextrin	0.55	2.25
Sugar	3.30	13.47
Albumen, casein, gluten	1.41	5.77
Fat	0.24	1.00
Fibre	3.26	13.31
	100.	100.

The true percentage of protein compounds is probably somewhat greater, as a portion of these adheres always to the starch and the fibre, and it hence would appear that the nutritive value of the dry potato is not very far behind the average of the finer varieties of flour, and is about equal to rice.

Potatoes, being composed, the skins excepted, of substances in solution, or such as are soluble in hot water (starch, cellular tissue), it would naturally be expected that they would fall to pieces, or dissolve when boiled in water; this, however, is not the case, and the fact is explained by the starch being surrounded by the cellular matter, which is only slowly and imperfectly acted on by water, and by the coagulated albumen of the tuber, which protects it against the action of the water.

Potatoes are somewhat heavier than water, for which property they are chiefly indebted to the starch, so that as a general rule, heavy potatoes contain more starch than light ones. In fifty-six different sorts the specific gravity of the potato was ascertained to be between 1.063 and 1.127. Lüdersdorf and Berg proposed to ascertain the actual amount of starch in every grade of the specific gravity scale of the potato, and so establish a relation between the two, which would enable the amount of starch to be calculated at any time from the specific gravity. Many errors might, however, creep into this mode of estimating the starch, particularly where large quantities are consumed, as in distilleries.

Real value of aliments.—As the result of the collection of facts already adduced, the conclusion may be drawn that the value of agricultural produce as food, is dependent chiefly upon the quantity of solid matter it contains, and the dry matter is valuable according to the relative proportions in which the heat-producing

and blood-producing ingredients exist in it. The figures in the following table, calculated from the accurate experiments of Horsford, Krocker, and Thomson, afford a means of comparing these relations at one view.

FOR EVERY SINGLE PART BY WEIGHT OF THE BLOOD-PRODUCING INGREDIENT (NITROGENOUS MATTER) THERE ARE CONTAINED:

	Parts by weight.			Parts by weight.	
	Heat-producing ingredient.	Starch alone.		Heat-producing ingredient.	Starch alone.
In Talavera wheat . .	4.890	3.405	In winter barley, Hoheim	4.556	2.164
In Whittington wheat .	4.598	3.069	In Jerusalem barley .	5.761	2.876
In Sandomierz wheat .	4.600	3.112	In Scotch barley . .	6.936	—
Mean .	4.696	3.195	Mean .	5.751	2.520
In wheaten flour from Vienna			In potatoes, white, Giessen	8.667	7.221
No. 1.	4.166	2.724	Ditto blue ditto.	11.560	9.793
No. 2.	6.310	4.964	Mean .	10.113	8.507
No. 3.	3.558	2.620	In Indian corn . . .	5.766	4.525
Mean .	4.678	3.436	In Indian corn-flour for polenta	6.220	5.695
In Triticum monococcum	6.403	4.139	In rice	12.38	11.65
In oats, Kamtschatka, Hohenheim . . .	5.646	2.615	In table peas from Vienna	2.402	1.385
„ reed-oat, ditto.	4.618	2.080	In field peas „ Giessen.	2.270	—
Mean .	5.132	2.347	Mean .	2.336	—
In (*Schilf*) rye, Hohenheim	4.561	2.543	In table beans from Vienna	2.337	1.314
In (*Stauden*) rye, ditto.	5.245	3.009	In large white beans from Giessen . . .	2.258	—
Mean .	4.903	2.776	Mean .	2.297	—
In rye-meal from Vienna.			In lentils from Vienna .	2.136	1.130
No. 1.	7.185	5.110	In sow beans from Scotland	2.263	—
No. 2.	4.225	2.915	In milk	2.5	1.5 fat and sugar.
Mean	5.705	4.012	In flesh	0.31 to 0.13	
In buck-wheat, Hohenheim	9.093	9.455	In tea*	2.07	
In buck-wheat flour, Vienna	13.300	4.439			

* According to page 110 and the following.

In order to form an opinion upon the value of any kind of food for practical purposes from these results, it must be first ascertained in what proportion the blood-producing ingredient stands to the heat-producing element in some normal food which is well known to be fully capable of supporting all the vital functions. This proportion must likewise have been established for the various circumstances of life, as it will vary according to age, mode of living, climate, &c. It may be predicted with the greatest probability that a man leading a mentally active, but sedentary life requires a different mixture of ingredients in his food, to one whose occupations demand an opposite kind of activity. Thomson pointed out a simple and ingenious mode of arriving at this information, so desirable towards the completion of our knowledge, by estimating the weight and the elementary composition of the food consumed by a cow, and the excreted matter during a certain period of time. From the two data the actual quantity of assimilated food may be calculated as well as the nature of the mixture of ingredients in that quantity. He found that a cow, stall fed, assimilated daily 15.28 lbs. of rye grass, in which 1.56 lbs. of nitrogenous, and 13.00 lbs. of amylaceous constituents are contained. The two, therefore, stand to each other in the proportion of 1 : 8⅓, a relation which very probably comes much nearer an equilibrium in man, and approaches that of the ingredients of flour 1 : 5, or 1 : 6. It may certainly be assumed that an infant assimilates in the same proportions as the ingredients are contained in milk.

In a table of rations (communicated by Liebig) of a regiment of soldiers who were fed upon meat, bread, vegetables, leguminous fruits, beer, brandy, and fat, the relation borne by the blood-forming to the heat-producing ingredients in the assimilated food, may be determined with a great approximation to truth, when all that is removed from the body in the shape of excrement is deducted; from this table it appears that 855 men consumed :

	Water.	Dry matters.	Proportion of the blood-forming to the heat-producing element in the latter.
Pounds of food together 4001 containing	1655	2346 lbs.	298 : 1357
Pounds of excrement 294 „	220½	73½ „	13 : 51
Relation of the blood-producing to the heat-giving portion of the assimilated food			. 285:1306 = 1:4.7

The quantity 4.7 which was deduced from the mode of living

of persons undergoing much bodily exertion, would certainly be diminished for persons leading a sedentary life. Although these figures in order to afford satisfactory evidence, must be deduced from much more extensive series of observations carried out on a large scale, they are nevertheless sufficiently near the truth, to afford ground-work for some important conclusions.

It is obvious in the first place that the proportions of mixture 1 : 4.7 (which is that for persons undergoing moderate bodily exertion) is exactly that which is common to the principal varieties of corn, to wheat, rye, barley and oats. Persons living entirely upon flesh, like many savage tribes and hunters, or upon the leguminous fruits, take in their food a very appreciable excess of the blood-producing ingredients, which can be counterbalanced either by such additional food as abounds in heat-producing elements, or by additional bodily exercise. The poorer classes of the population with us are placed in a precisely opposite position; they are limited, in consequence of the existing social conditions, to the poorest kind of food, the potato. The potato only contains in the state in which it is consumed one half as much of the blood-producing constituents as the cereal grains; nature has, therefore, in this case to combat with an actual want, which is a far more difficult task than the removal of an excess, and her only assistant is instinct, which drives the poor, whenever their wages admit of it, to seek a remedy in the consumption of bread, milk, cheese, coffee, &c. In every case it must be admitted that the mode of life of the poorer classes, is forced to an unnatural extreme, by the excessive wretchedness of their whole state; this straining of natural laws may be exhibited possibly in three different results; it may lead to a deficiency of bodily power and loss of health, but this is not the most prominent; or to increased mortality and shortness of life, upon which points statistics ought to furnish information; or lastly to a want of mental energy, to a kind of stupid indifference, and carelessness about everything beyond the merest animal wants, and this is indeed the usual result. Living upon potatoes, these classes of the community are, as it were, at the last stage of existence, or have no further prospect before them. For this reason the partial failure of the potato crop, incites the masses in all parts to agrarian outrage and rebellion, a most significant fact; for it is certainly true that the German or Irish peasant solves the problem of living upon the least possible amount of food, and that of the very worst quality.

The application of the potato to the manufacture of spirits, consists in a separation of the excess of the heat-producing ingredient, the starch, from the remainder; the albuminous residue with the gluten of the malt form together a very appropriate half-dissolved mixture for alimentary purposes, which can be given with straw, or other inferior kinds of fodder to suit it to the digestive powers of graminivorous animals. As the potato contains ten times as much starch as albumen, the half of it may be economically converted into spirits, leaving a residue of the same constitution as that of the cereals (or in the proportion of 1 to 5).

OF TEA.

Source.—It appears from the observations and reports of numerous travellers, that all the varieties of tea are derived from the leaves of two species of the same shrub, the *thea chinensis* and *viridis*, which belong to the family of the camellias, and exhibit to that family the greatest outward resemblance. The general use of the infusion of tea was common in China, in the beginning of the sixth century after Christ, but was only introduced into Europe by the Dutch East India Company in the beginning of the seventeenth century. About the year 1666, the first tea was introduced into England, and it is only within the recollection of the oldest persons that it has become a national want. The Chinese call it *tscha;* in the dialect of the province Fokien, it is *tiá*, whence are derived the European appellations *tea*, *thé*. The tea districts of China are situated between the 24th and 25th degrees of north latitude, so that the tea shrub may be called a sub-tropical plant; two districts are located upon this zone, a westerly district which is isolated, and an eastern district which affords a supply for a double traffic, partly over land through Kiachta, and likewise by sea.

According to Ball the tea plant has been found indigenous in China between 23° and 33° north latitude, and its cultivation extends over 28° of latitude, and 30° of longitude. Various accounts tend to show that severe frost and occasional snow prevail in the tea districts, and on some occasions, though rare, as late as the vernal equinox. The frost is, however, probably not very intense, or of long duration, while the plant is everywhere exposed to the intense heat of a vertical sun. It is indigenous to sea coasts, islands, as Chusan and Japan, and to the interior and western extremity of the empire, as in Szu-chuen,

beyond all influence of the sea. It must consequently be an extremely hardy plant, and capable of adapting itself to great varieties of climate and circumstances. The propagation of tea is by the medium of seeds; it requires no manure, and a poor soil, which should be moist, and have a southerly aspect on the sides of hills and mountains. Other authors state that a rich soil, which should be moist, is more favourable to the growth of the plant, and that an easterly aspect is to be preferred.

Nees von Essenbeck and L. C. Marquart analysed the soil from a Japanese tea plantation with the following results:

Silica	53.
Oxide of iron	9.
Clay	22.
Oxide of manganese and magnesia	0.5
Sulphate of lime	0.5
Humus	1.
Phosphoric acid	traces
Water, hygrometric	14.
	100.

The soil therefore appears to be a strong ferruginous clay containing much siliceous earth, and cannot be called rich, it is entirely deficient in carbonate of lime and the alkalies. Mr. Faraday likewise examined several specimens of soil from the Bohea tea districts, and found them totally deficient in lime.

Von Siebold states, that in Japan, both solid and liquid manure are largely applied to the growing tea plant, and are found by experience to be suitable to the heavy soils that are congenial to it, and to exercise a decided influence on the improvement of the shrub. These remarks apply, however, more to the plants intended for the production of green than black tea.

The tea shrub produces its first crop in its third year, but has not then attained its full growth. In its seventh year it acquires the height of a man or more; it then produces a scanty crop of hard leaves and is cut down, when shoots spring up from the root; the operation is repeated until the plant dies in its thirtieth or fortieth year.

Varieties.—In commerce two kinds of tea are principally known, namely *green tea,* and *black tea,* which may be made from the leaves of the same plant. To the green varieties belong Twankay, *Hyson, Haysan,* or *Hayswen,* Imperial and Gunpowder; among

the black teas, Bohea, Souchong, Pekoe, and Congou, are the most remarkable. The varieties and sub-varieties are occasioned by the various times of collecting, by the degree of development in the growth of the leaf, and more particularly by the method employed in preparing the tea for commerce.

The crop is harvested at three periods; in the middle of April, in June, and in July, a lesser quantity being collected each time, and in all about 2 lbs. yearly from one shrub.

Ball states, "the gathering takes place during the spring after heavy rains, when the shrubs shoot forth leaves vigorously and abundantly. This period of gathering lasts, at intervals of ten or more days, from about fifteen days after the vernal equinox to about the same number of days after the summer solstice. There is also an autumnal gathering, which, however, affords weak tea of inferior quality. Most of the Chinese accounts agree that the gathering of the leaves commences with the Pekoe tea, and lasts from the 5th to the 20th of April. This tea consists of the convoluted leaf-bud. The first gathering of the expanded leaf commences between the 20th of April and the beginning of May; the second about the 6th of June; the third after the 21st of June; and the autumnal gathering in August and September. The coarse leaves, which form the common Bohea, are collected in September and October. In the successive gatherings the young and succulent leaves only are chosen, if the leaves be permitted to attain their full growth they become harsh, fibrous, and brittle, and cannot be made to assume the twisted form in their manipulation, but remain flat, coarse, or open, and yellow, and are unfit for tea."

Mr. Jacobson of Java thus describes the gathering:

"The gathering is divided into three classes of leaves, and each class is gathered by different men. First, the top-leaf, consisting of the convoluted leaf-bud with its expanding or expanded leaf; then the fine-leaf tea, consisting of the second and third leaves; and, finally, the fourth and fifth leaves, which form the middle-leaf tea. The coarse-leaf tea is the refuse of these two classes after manipulation. It is the duty, also, of the gatherers of the middle-leaf tea, as they are the last gatherers, to search for and gather any other delicate leaves which may have been overlooked by the previous gatherers. The mode of gathering is by turning the thumb downwards, and nipping off the young green succulent shoot with the nail and forefinger, first below the top-leaf, with its expanded or expanding leaf; then below the second and third,

and the fourth and fifth leaves. If the sixth and seventh leaves are fit for tea, they may be gathered also.

"When the last leaves on the shoot are gathered, they must not be nipped off, but plucked upwards, and in such a manner as not to injure the buds; otherwise such shoots or branches would be left without the power of reproduction. It is desirable that two, but not more buds, should be left on each shoot; and the separation should be made about a quarter of an inch from the nearest eye or bud intended to be preserved for the reproduction of young shoots. The stalks of the leaves of black tea must not be detached from the leaves, because, in the process of withering, they improve the flavour of the tea, and do not impede the rolling of the leaves, because they are tender, pliant, and succulent.

"The green tea leaves are gathered without their stalks, because the withering of these leaves would be injurious. The stalks are, consequently, not nipped off, but the leaves plucked upwards.

"The gatherers carry a small basket in front of them, fastened round the body; thus they are enabled to gather the leaves with both hands, and to throw them quickly into the basket. They must not be kept long in the hand, nor in large parcels, lest they should heat and turn sour. Besides the small basket strapped to the body, there are four large baskets each carrying about 3 lbs. of leaves, required for each section of a garden; so that two may remain while two are sent off to the roasting-sheds: one is required for "fine-leaf," and one for "middle-leaf." The Pekoe and Gunpowder leaves are kept in "*scoop-baskets*," their quantity being small. The baskets containing the leaves of black tea may be left open and exposed to the sun to hasten the withering; but the leaves of green tea must not be exposed to the sun, nor should they be kept long in the garden; nor must the black tea be allowed to wither rapidly, lest they also heat and turn sour.

"After the fourth gathering, the shrubs will once more exhibit an abundant display of foliage; but these leaves must be left to restore the exhausted energy of the plant."*

The mode of preparing tea witnessed by Guillemin in the Brazils, and by Von Siebold in Japan, as well as that described by Bruce, as practised in Upper Assam, accords perfectly with the descriptions given by Clarke, Abel, and other travellers in China. The

* Abstracted from the Handboek v. d. Kultuur en Fabrikatie van thee d. J. J. L. L. Jacobson. Batavia, 1843.

latest and best is that of S. Ball, from whose compendious work we have taken the greater part of the following descriptions.

Mode of preparing black tea.—According to older accounts, black tea is the result of drying and *roasting* the tea leaves over the naked fire, while green tea is obtained by *withering* the leaves in steam, and simply drying them afterwards. Black tea would therefore stand in the same relation to green tea, as kiln-dried malt to malt dried in the air.

When the leaves intended for the production of black tea are properly sorted, they must be put in process on the same day. They are exposed to the rays of the sun in sieves made of bamboo, in a slanting direction, until they begin to shrivel, which is accelerated by beating them between the hands. There appears to be a difference of opinion even among the Chinese themselves respecting the expediency of drying the leaves in the sun previously to roasting; but according to Ball, all the Congou teas in the tea country are exposed to the sun, where large stands are erected in the open air for this purpose. The stands are sometimes arranged horizontally, but more frequently obliquely, and usually contain about three rows of trays, each 2½ feet in diameter. The stands are raised 2 feet from the ground, and incline outwards at an angle of 25° towards the sun, as shown in Fig. 12. The

FIG. 12.

finest Souchong and Paochong teas, which are prepared from the most delicate young leaves, of great succulency, would be injured by exposure to the direct rays of the sun; and being gathered in the finest weather under a tropical sun, become sufficiently dried by mere exposure to the air in the shade. Leaves of inferior quality, on the other hand, and such as are gathered during rain, require to be dried before or over a fire previously to being roasted, for if turgid and full of juice, they would be boiled instead of roasted in the pan or *kuo*. Different methods are adopted for thus artificially drying the leaves, one of which is shown in Fig. 13, taken from a Chinese drawing. It exhibits

FIG. 13.

a room fitted up with framework to receive the sieves, with earthen chafing-dishes containing charcoal placed underneath. After being dried, the leaves must be cooled, to check fermentation; they are consequently placed in three layers, upon bamboo trays, arranged on tall stands, consisting of many stages, and exposed in shady situations to the wind in the open air, or in buildings which admit of a thorough draught through them. Here they remain until they begin to emit a slight degree of fragrance, when they are sifted, to rid them of any sand or dirt which may adhere to them, preparatory to being tossed about with the hands and arms, in the

manner shown in Fig. 14, which is kept up for a considerable time, until they have acquired the necessary degree of fragrance. In Java, in addition to this shaking with the hands, the leaves are whirled

FIG. 14.

round in trays, an undulatory motion being given to the trays from right to left, by a slight action of the arms and hands, so as to keep the leaves in constant agitation. Mr. Jacobson, of Java, has invented a machine for performing these operations, consisting of a cylinder revolving on its axis, and shown in Fig. 15. The leaves are often covered with a cloth after these operations, and carefully watched until they have become spotted and tinged with red, when the fragrance increases, and they must at once be roasted. These operations pre-

FIG. 15.

paratory to roasting are considered very essential to the quality of tea, although the fragrance spoken of has no resemblance to that of the fully manufactured tea. A slight degree of incipient fermentation may be the result of these operations, analogous to that which causes the fragrance in hay, and whatever the change may be, it is certain that the quality depends upon its proper management.

The roasting takes place in a shallow, remarkably thin, iron vessel, called a *kuo,* which is of a circular form, differing in no respect from those used in China for culinary purposes, except that it has no handles. It is represented in Fig. 16, and is about 2 feet 4 inches in diameter, and 7¾ inches deep; it is fitted horizontally into a stove, with its rim even with the upper surface of the brick-work. The fireplaces are on the back side of the stove. The fire in the first roasting is made with dry wood, and the pan heated considerably above the boiling temperature. The roaster, as described by Ball, and as represented in Fig. 17, stands on the side of the stove

FIG. 16.

FIG. 17.

opposite the fireplace, and taking about half a pound of leaves between his hands, he throws them into the kuo. He then places his hands upon the leaves, and with a slight degree of pressure, draws them from the opposite sides of the vessel across the bottom to the side nearest to himself. He then turns them over and throws them back again, repeating this action until the leaves are sufficiently roasted. When the heat becomes excessive and difficult to bear, the roaster then raises the leaves some height above the kuo, and shaking them on his hands, he lets them gradually fall, which serves to dissipate the steam and to cool them; great care is requisite that none of the leaves burn on the bottom of the vessel, which would impair the flavour of the tea. The roasting is continued until the leaves give out a fragrant smell and become quite soft and flaccid, they are then immediately rolled or kneaded with the hands in the manner represented in Fig. 18. Each roller

FIG. 18.

is provided with a circular tray of bamboo work, upon which he places as many leaves as the two hands held together in a concave position (Fig. 19) can cover. The leaves are then rolled from left to right, with a slight degree of pressure, keeping them as much as possible in the form of a ball closely collected under the hand. It is in this part of the process that the leaves become twisted, and the viscous juices expressed in the process of rolling are sufficient to keep the leaves in the twisted form. The leaves may be as skilfully rolled with the feet as with the hands, and this is often practised as a relief to the former. They are now spread out on clean trays, and placed on stands several tiers in height, until the whole of the

FIG. 19.

fresh leaves have been roasted, when they undergo a second roasting. The heat of the fire is considerably diminished in the second roasting, and charcoal is used instead of wood for heating the pan. The bulk of the leaves being considerably lessened, more of them can be placed in the kuo at once; they are frequently shaken and strewed round the less heated sides of the vessel, to accelerate the evaporation of the steam by the admission of air and to cool the leaves. They are then again rolled as before, and again roasted and rolled as long as any juices can be freely expressed in the process of rolling. When that ceases, they are then in a condition to undergo the final desiccation denominated "Poey."

The finest kinds of tea, such as Yen or Padre Souchong, are treated in a somewhat different manner previously to being roasted as described. A pan represented in Fig. 20, set in an inclined

FIG. 20.

position is heated to redness, and a man standing on the right of the roaster throws about 2 oz. of leaves smartly against the kuo, the roaster seizes them with his hands, gives them a brisk turn round the kuo, and sweeps them into a tray which another man holds in readiness to receive them. Three or four ounces of leaves are then thrown upon the brickwork, and the roaster tosses them against the heated part of the vessel. They are then collected together, and having been turned rapidly two or three times round the less heated part of the kuo they are swept out as before. The leaves are now put aside to cool, and then roasted three times, as already described. This operation is, however, only practised with the finer teas, such as are never or rarely intended for exportation.

The final desiccation is conducted in open sieves over a bright charcoal fire, and requires great watchfulness that no leaves fall through the sieve into the fire, and so give rise to smoke, which would injure the flavour of the tea. The sieves are placed in a tubular piece of basket-work, called a *Poey Long*, shown in Fig. 21, about 2½ feet in height, and 1½ in diameter, open at

FIG. 21.

both ends. It is covered with paper, and is slightly contracted in the centre, a little above which contraction two cross wires are placed for the purpose of supporting the sieve containing the tea, which is placed about 14 inches above the fire. The drying tube covered with a bamboo tray at the mouth, and containing the tea which has been previously sifted from dust upon the sieves, with a hole left in the centre of the heap to allow any smoke to pass off, is placed over a low stove built upon the ground to contain a small quantity of charcoal. The stoves are constructed

within a continuous piece of brickwork coated with plaster, extended round three sides of a long narrow room; the brickwork being about 5½ inches in height, and 2 or 3 feet in depth from the front to the wall. A considerable quantity of steam escapes in this process, although no more could be expressed by rolling. The leaves are suffered to remain about half an hour in the drying tube, and are then turned, the sieves being taken out, and covered by another sieve, the two being then inverted, when they are again placed over the stove for some time before being rubbed and twisted between the hands.

The rubbing between the hands being accompanied by a slight degree of pressure twists the leaves in a permanent manner, they begin to assume likewise their black appearance, but require to be again dried over a smouldering fire, and twisted two or three times until they have become perfectly dry and crisp. The leaves are then taken from the fire and sifted, the old and yellow leaves being winnowed off by means of a large circular bamboo tray, and if necessary the coarse leaves picked out by hand; the remainder are then again placed over a very slow fire in much larger quantities at a time, for about two hours, or even longer, the mouth of the drying tube being quite closed with a tray. The tea is then packed in chests or baskets for sale.

The methods here described apply to the best kinds of Paochong, Souchong, and Congou teas; the manipulation of inferior kinds is carried on in a much more slovenly manner. Some are simply dried in the sun, rolled by means of a channelled and roughened stone, Fig. 22, with hollowed sides for the convenience of lifting, the balls of leaves thus produced being pulled to pieces, and the operation repeated several times after continued exposure to the sun. Tea thus prepared has a fragrant smell, and is redder in colour, with a sweet taste, but is not calculated to keep well.

FIG. 22.

Pekoe tea is prepared from the leaf-bud before it is expanded, in which state it is covered with white hair or down (Pe-hao signifying white hair). These white downy leaves have been supposed to be the blossom of the tea plant, and hence this kind of tea has

been called *fleur de thé*, and flower by the English dealers. The tea-flower itself has little fragrance, and although sometimes used in China is never mixed with exported tea.

This kind of tea is very slightly rolled—if at all. It is dried in the sun, then over a slow fire, and lastly in a drying tube. It frequently acquires a musty smell from being imperfectly dried, and its peculiarly red appearance is said to be produced by a lengthened process of tossing the leaves on trays, or whirling them round on sieves covered over with another tray to promote the withering.

The Sonchy or caper tea, so called from the fancied resemblance of the roundish pieces of which it consists to the caper, is prepared only from the largest of the young succulent leaves, each leaf being, it is said, plucked separately from the shrub. The process usually carried on in the drying tube is separated, in preparing this tea, into a series of short dryings and rollings, which together have the effect of causing the tea to stick together like a ball, which, when broken, does not fall to pieces in separate leaves, but in fragments, which can be rolled into the roundish nodules from which the tea has received its English name. This is an expensive kind of tea, and is always more or less scented with the Chu-lan flower (*Chloranthus inconspicuus*) in the following manner.

Scenting is seldom practised except upon inferior teas, the fragrance of fine teas being incapable of improvement. The flowers used for scenting are best collected with the dew upon them; a layer of tea, about 2 inches thick, hot from the last roasting is thrown into a Hyson chest, and a handful or more of the fresh flowers separated from the stalks thrown upon it; a second layer follows this, and then more flowers, and so on until the chest is full; the whole being then closed up is left for twenty-four hours. On the following day the chest is emptied, and the flowers mixed with the tea are roasted together for an hour or two until the flowers become crisp. The flowers are then sifted out, and the tea is packed. Tea thus prepared serves to mix with other kinds. One part of scented tea added to twenty of plain, and slightly heated in a kuo, constitutes, when packed, the description of tea known as Cowslip Hyson in England.

Black tea, however, is scented in a somewhat different manner: the flowers, having been dried in the sun, and afterwards in the drying tube, are reduced to powder, and a quantity of this powder

is then sprinkled over the tea before it undergoes the last process of roasting. Souchong tea is sometimes scented with the flowers of *Gardenia florida, Olea fragrans,* and the *Jasminum Sambac.*

Bohea tea is the coarsest description that is exported, consisting of the full-grown leaves, which remain on the shrubs after the regular tea harvest has been gathered. The leaves are collected in a very rough manner, by passing the hand along the branch; they are exposed to the sun or air for a short time, and then packed in baskets. In the Bohea country the purchaser of the crude tea sends it to his own roasting house. In the Wo Ping country it is generally packed in tubs, and sent to Canton to be roasted. There it is sifted, assorted, and loosely repacked into bamboo barrel-shaped baskets slightly put together, and of somewhat open work for the better admission and circulation of hot air; the inside being lined with soft paper to prevent loss of tea.

The drying houses at Canton, Fig. 23, are constructed of brick,

FIG. 23.

and divided into several chambers all on the ground-floor. Each chamber has a door in front, with a small opening at the bottom, to which a slide is fitted that can be opened and shut at pleasure. This opening is for the admission of a long rake for stirring the charcoal, and another aperture with a shutter is made at the opposite side of the chamber, to allow a thorough draught to

circulate through it for kindling the charcoal or cooling the tea. A channel about 16 inches in width is erected on the tiled floor of the chamber, and extending through nearly the entire length; upon this the charcoal, after having been kindled in heaps, is spread out with rakes. The baskets are laid on their sides and arranged in six tiers upon an open framework on both sides of the chamber, with their mouths toward the charcoal fire in the centre, a piece of lead closing the end of the basket to prevent the fire overheating the tea. Each tier contains about twenty baskets, so that there are one hundred and twenty on each side of the chamber. The usual quantity roasted at one time in the several chambers is sufficient to pack four hundred large chests of Bohea, or about 70,400 lbs. The roasting usually lasts three days, the charcoal being renewed every six hours, 1 lb. of charcoal being consumed for every 5 lbs. of tea roasted. The chambers vary from about 28 to 41 feet in depth, 9 to 14 feet in breadth, and from 10 to 15 feet in height.

The tea thus roasted is well mixed with other somewhat superior kinds, according to the quality required, and is ultimately packed in large or whole chests, containing on an average 172 lbs.

In good tea, the leaves should be well rolled, and as perfect as possible. It cannot be denied, that the quality of tea is dependent in a far higher degree upon the skill in its preparation, than upon the original value of the leaves, and that European facilities for manufacture might exercise a most important influence upon the value and uniformity of the produce.

Of green tea.—The leaves intended for the production of green tea are spread out in layers upon hurdles, in a kind of box, made of bamboo, the bottom of which forms a water-boiler. The aqueous vapour passing through the leaves soon withers them, they are then rolled, and placed at once in the iron-pot to dry. The light-green colour of this tea is accounted for by the fact well known to collectors of plants, that many plants, (like the *Orchideous*), which inevitably turn black when simply dried, preserve their green colour in the most brilliant manner when they are killed by steam previous to drying between blotting-paper. Green tea gives up much less of its juice in the drying process—a circumstance which fully explains its more energetic action upon the nervous system.

The description given by Ball differs somewhat from the above. He states that green tea is of two kinds, *Hyson* or *Singlo*, according

to the shrubs from which it is obtained, and, indeed, the plant affording the former of these appears to be identical with that which furnishes Singlo, only improved by soil and cultivation. All green tea comes from the province of Kiang Nan, and was originally called Singlo from a hill where it was grown and prepared; being afterwards introduced into the plains, and more attention bestowed upon its culture, it received the name of garden tea, and ultimately Hyson, from the firm or mark, Hee-Chun, of a distinguished maker. The leaves are gathered twice a-year, in the months of April and May, and again at the summer solstice; the sooner they are roasted after gathering the better, all exposure to the air and sun being injurious, excepting so far as to prevent their heating and turning yellow previous to roasting. They are exposed on tiled floors or in shallow bamboo trays in shady places, the stalks being picked off carefully, and dust and dirt sifted from them. The pan, or kuo, in which green tea is roasted, is a thin cast-iron vessel, shown in Fig. 24. It is deeper than that used for black tea, the sides being partly perpendicular, and is set in a brick-work stove in a horizontal position, at about 5 inches from the level of the upper row of bricks. The depth of the pan is 10 inches, and it is 16 inches in diameter, the interior being kept quite bright by constant friction. Fig. 25 shows a section of the stove. In roasting green tea, a bright fire is made in the stove, Fig. 26, so as to heat the pan or kuo very considerably above a temperature that can be borne with the hand, in fact, nearly to a red heat, ½ lb. of leaves are then introduceed, and are stirred about, first with one hand and then with the other, producing all the time a crackling noise and a great quantity of steam, which from the depth of the pan is not

FIG. 24.

FIG. 25.

FIG. 26.

enabled to escape so readily as from the shallow kuo used for black tea. The roaster, however, raises the leaves every now and then to about 6 inches above the surface of the stove, and shakes them over the palm of his hand, to separate them and disperse the steam. The process is continued until the heat becomes excessive; the leaves are then turned two or three times briskly over the kuo, and swept out into a basket, held in readiness by another man. The rolling or kneading is performed in precisely the same manner as is done with black tea. After being sufficiently twisted in the hands, they are spread out on sieves and allowed to cool for a short time, but the sooner they are put through the second process of roasting the better. The fire is considerably diminished in the second roasting, charcoal being used in place of wood, but the kuo is still kept so hot that the finger cannot bear the heat longer than a second, and great attention is paid to the regulation of the heat, a man being employed to tend the fire constantly, while a person fans the leaves throughout the entire process, as shown in Fig. 27. The roaster presses the leaves with both hands against the bottom

FIG. 27.

of the kuo, drawing them towards him, and constantly shaking and occasionally twisting them, until from loss of moisture they have no longer any tendency to unrol. On leaving the pan after this second roasting the leaves present a dark olive colour, almost black, and after being sifted they are roasted a third time, in larger quantities at a time and at a more moderate temperature, the fanning being continued throughout. In this last roasting a peculiar change of colour takes place, the leaves become covered with a bluish tint, resembling the bloom on fruit, which is the distinguishing character of this species of tea. Until this colouring appears no rest can be allowed the workmen, as it alone is the test of the leaves being thoroughly dried. The three roastings occupy about ten hours, the original quantity, 33 lbs., requiring the entire attention of one roaster. The crude product of these roastings is called Mào-Cha, and when not sorted on the spot, is sent to Canton, where it is passed through different sieves, and winnowed by tossing on large bamboo trays, as shown in Fig. 28, and at last is passed through a winnowing machine, like that used for separating chaff from wheat, by which means, and by subjecting

FIG. 28.

the produce of the sieve to several short processes of drying, it is assorted into four principal classes, known as Hyson, Hyson skin, young Hyson and gunpowder. These are then mixed or arranged according to the quality required, previously to packing.

FIG. 29.

Singlo, or Twankay tea (Tuon Ky), is prepared in the same manner, only with less care than Hyson. The operation of rolling is often performed with the feet as a relief to the hands, and the Twankay kuo, Figs. 29 and 30, resembles that used for black tea, only that it is placed obliquely at an angle of 16^0 on the stove, and at about 9 inches below the surface, its depth being about 8, and its diameter 24 inches. This tea

through muslin, the colouring matter may be effectually separated. The washed leaves have a very different appearance when dry; they are as dark as black tea, with a smooth, and not so wrinkled a surface. The unglazed tea of the English tea-dealers has precisely the same appearance. This tea is either dark-brown or yellowish-brown, without any tinge of green or blue; its surface is only covered with some gypsum.

Amongst the substances employed for adulterating tea, the leaves of the *Stachytarpheta Jamaicensis,* belonging to the family of the *Verbenaceæ,* are very frequent, and also the leaves of native plants, as of the *Sloe,* and others.

The result of the chemical examination of tea is interesting for several reasons.

Water.—The different varieties of tea all lose nearly 4 per cent, according to P. Mulder, by a complete process of drying at 100° C. (212° F.) Peligot, on the other hand, found on examining twenty-seven varieties, that the black teas lost 8 per cent, and the green teas 10 per cent, by drying at 110° C. (230° F.)

Chemical constitution.—Besides the substance of the cells and vessels of the leaves, which in black tea amount to from 27 to 28 per cent, and in green tea (prepared in the manner first described above) to only 17 to 18 per cent, all varieties of tea contain, without exception, from 4.76 to 5.56 per cent of ash, which is composed of sulphuric acid, phosphoric acid, hydrochloric acid, lime, potash, oxide of iron, and silica. The remainder consists of vegetable substances, which can be dissolved and extracted by different liquids; these are partly of the kind common to all vegetables, as gum, wax, resin, chlorophyl, &c., and partly characteristic and peculiar to tea; viz.: a *volatile oil, tannic acid,* and *theine.*

The following table shows the composition of Chinese and Java tea according to P. Mulder's analysis:

	Chinese.		Java.	
	Hyson.	Congou.	Hyson.	Congou.
Ethereal oil	0.79	0.60	0.98	0.65
Chlorophyl	2.22	1.84	3.24	1.28
Wax	0.28	0.00	0.32	0.00
Resin	2.22	3.64	1.64	2.44
Gum	8.56	7.28	12.20	11.08
Tannin	17.80	12.88	17.56	14.80
Theine	0.43	0.46	0.60	0.65

	Chinese.		Java.	
	Hyson.	Congou.	Hyson.	Congou.
Extractive	22.80	19.88	21.68	18.64
Apothem	traces	1.48	trace	1.64
Muriatic acid extract . . .	23.60	19.12	20.36	18.24
Albumen	3.00	2.80	3.64	1.28
Fibrin	17.08	28.32	18.20	27.00
Salts contained in the above-mentioned constituents . .	5.56	5.24	4.76	5.36

The tannic acid is very similar to that which occurs in the bark of the oak, and in gall-nuts, and has the property, in common with it, of precipitating the salts of iron of a black colour. According to the above analyses, the quantity of this acid in green tea, is very much greater than in black tea, being nearly 18 per cent in the former, while it is only from 13 to 15 per cent in the latter.

Aroma.—The volatile oil of tea is of a citron-yellow colour, becoming easily solid, it floats on water, and is quickly resinified when exposed to the air. It has such a powerful taste of tea, that when placed on the tongue it spreads over the entire throat, and exerts a powerful action on the nerves, producing trembling, and similar affections. When tea is distilled with water, the oil separates, and is volatilized; by boiling, or infusion, it is extracted by the water, which becomes impregnated with it. It is obvious that a large portion of this oil must be lost in drying the tea, if it already exist in the leaf, and is not a product of the drying process, which appears probable. It is contained in green tea to the extent of 1 per cent, and in black tea to about $\frac{1}{2}$ per cent. There is no doubt that the action of tea upon the system is in great part due to this oil, although the theine is the more efficient cause.

Theine.—Theine is a compound of carbon, hydrogen, nitrogen, and oxygen ($C_8 H_{10} N_4 O_2$), which neutralizes acids, and is thus allied to the organic bases. Crystallized from water, it combines with 2 equivalents, or 8 per cent, and as a hydrate, forms beautiful white, silky needles. These lose their water of crystallization at 100° C. (212° F.), melt at 178° C. (353° F.), and are volatilized unchanged at 385° C. (725° F.); the theine cannot consequently be volatilized at the temperature at which tea is dried. Theine is easily soluble in hot water, much less in cold, and amongst ordinary reagents, tannic acid is the only substance that precipitates it, forming with it an insoluble substance in cold, but soluble in hot water. Theine has no smell, but a slightly bitter taste. Theine

is to tea, what quinine is to bark, that is to say, the exciting effects of tea must be attributed chiefly to this constituent, although the small quantity contained in tea made this at first appear doubtful. Mulder first stated the amount in tea to be ½ per cent. Stenhouse afterwards obtained 1 per cent; and, lastly, Peligot proved that there could not be less than 6 per cent in dry tea. The large amount of nitrogen in tea-leaves corroborates the latter statement, as these contain more than *twice as much* as is found in rye or wheaten flour, and more than one-half of the nitrogen is contained in the aqueous decoction, which must be solely attributed to the theine.*

Casein.—There is another nitrogenous constituent contained in tea besides theine, which is only dissolved by water when a little potash is added to it; this substance, according to Peligot, is precipitated by acids, and resembles in general characters the casein described at page 41; it is retained in an insoluble state in the leaves, in combination with tannic acid.

Decoction of tea.—It is obvious, from the foregoing observations, that only a portion of the substances contained in tea-leaves is soluble in water, and can be communicated to the decoction as it is consumed in China and in Europe. The portion extracted by hot water from black tea varied in six specimens, according to Mulder, from 29 to 38 per cent; in the same number of kinds of green tea, from 34 to 46 per cent. Peligot found in black tea 38 per cent, in green tea 43 per cent, as the mean quantity contained in the commercial undried article, and estimated the amount of nitrogen in this soluble portion, which must be solely due to theine, at 4½ per cent in each kind. Thus, from 100 parts of tea, supposing it to be entirely exhausted, 6 per cent of theine would be contained in the decoction; in domestic economy, however, by the ordinary method of extraction, the entire quantity is never dissolved, about one-third being left in the leaves; for instance, 100 grains of gunpowder tea infused in 10 lbs. of water, yielded 31 grs. of extract, containing 5 per cent of theine. The ordinary extract of tea contains the volatile oil, the theine combined with tannic acid, besides gum and some other extractive matters. The whole of the oil of tea would be lost by boiling; with lukewarm or cold water, little or no theine would be extracted. The combination of theine with tannic acid can only be properly extracted by pouring boiling water upon tea in close vessels, and the aromatic

* One part by weight of nitrogen corresponds to 3.47 parts of theine.

oil remains at the same time in solution in the water without being volatilized. A good decoction of tea, as is well known, becomes turbid on cooling, and is covered with a skin, caused by the separation of the tannate of theine.

The perfectly exhausted tea-leaves still contain 4½ per cent of nitrogen, or about the half of the entire quantity contained in commercial tea; should Peligot's assertion prove true, that this nitrogen belongs to the casein, which, being in combination with tannic acid, is not soluble in water, then there must be about 28 per cent of this substance contained in the exhausted leaves, and about 15 per cent in commercial tea. There can, therefore, be no doubt that (according to European custom) a very considerable quantity of the most nourishing ingredient is allowed to be wasted, and is used only by those who not merely consume the decoction, but likewise eat the leaves as a vegetable. An illustration taken from Peligot's researches will prove this statement:

100 parts of gunpowder tea afford:			100 parts of Souchong afford:		
Water	10		Water	8	
Extractive . .	47 with	Volat. oil 0.5 Theine 6.0	Extract . . .	43 cont^{s}	Volat. oil 0.5 Theine 6.0
Exhausted leaves	43 cont^{s}	Casein 12.0	Exhausted leaves	49 cont^{s}	Casein 14.0
	100			100	

The nomadic races that inhabit an extensive district of Middle Asia, the Mongols and Burates, consume tea, not only as a drink, but as a vegetable. They import a particular kind of tea, called brick tea, from their Chinese neighbours, and what they themselves do not consume is sent to Siberia, and partly to Astrachan, for the Kalmucks. Brick tea is in such very general demand, and has become so popular a necessary, that it is employed everywhere in Mongolia and Daurien as an article of barter. The distribution of tea in those countries is ascribed to the practice of the Emperors of the Mandschus, who paid their Mongolian troops with cakes of tea. This Chinese product, which is never consumed in China, consists of the old coarser kinds of tea-leaves, the refuse and stalks of the better kinds, mixed with the leaves of other shrubs, which ingredients are incorporated with the serum of ox or sheep's blood, and formed into thick four-sided cakes, whence the Russian name for them, *Kirpitschnoï Tschai*, or *brick tea*, is derived. It supplies these nomadic races with a very portable food, which renders the very worst water of the Steppes drinkable. They are in the habit

of rubbing it up with water, and boiling it with the addition of some flour and suet, of beef, mutton or horse (or, in case of need, a tallow candle) into a kind of broth, which they take with the salt of the Steppes, and, if possible, with ashes or other alkaline salts. The latter is obviously used, though unwittingly, to dissolve the casein as much as possible.

The general size of the brick tea lumps is 16 inches in length, 5½ in breadth, and 1½ in depth, their weight being about 7½ lbs. Dr. Falconer met with cubes of this tea, however, which were only 9 inches across. These tea-cakes differ much in appearance, some appear to be composed of leaves wetted, and forcibly compressed; others of leaves rolled like ordinary tea, and some as if the leaves had been macerated in water, and reduced to a pulpy state. The angular form of the tablets clearly indicate that a mould, and considerable pressure have been used in their production. Their cohesion is said by some to be produced by a solution of rice as well as with the serum of blood. In quality these teas may be classed with common Bohea, and the great bulk of them are the produce of the province of Szu-chuen, one of the border provinces adjoining Thibet. The preparation of brick tea for consumption, milk, salt, or butter, is said to require much time and care, so that the tea-cook is an important domestic in the train of every substantial Kalmuck.

Paraguay tea.—Paraguay tea supplies the greater part of South America, Paraguay, La Plata, Peru and Quito with a substitute for the ordinary tea consumed in Asia, Europe and North America. It is a similar product, obtained from a kind of holly (*Ilex Paraguariensis, St. Hilaire*), indigenous to Paraguay, Uruguay, and the interior of the Brazils, where it attains the size of an orange-tree, with narrow spatula-shaped leaves, 3-4 inches in length, and is called *Yerva maté,* and by the Indians *Cau-Coup.** The Paraguay tea of commerce is of a dirty yellowish-grey colour, a mixture of very small pieces of leaf, with stalks an inch long, and part of the stems, which have been artificially dried over the fire. In Paraguay, this method of preparation affords a better tea than in the Brazils: its taste is very peculiar, but somewhat similar to the inferior kinds of Chinese tea. The use of this tea, which has spread from the natives at the Conquest to the Portuguese, produces an unpleasant excitement, which is subdued

* An inferior kind of Paraguay tea appears also to be obtained from the *Cassine Gouyouha Mart.*

by opium. It is taken as an infusion, like Chinese tea, sometimes with sugar, or with lemon-juice. Much less is known of the nature of Paraguay than of Chinese tea. Trommsdorf discovered catechuic acid in it (a kind of tannic acid), and Stenhouse, theine. The latter found in it, only 0.13 per cent of theine, by a method which in the case of Chinese tea only yielded ¼ of the actual quantity.

European nations are separated into two classes with reference to the consumption of these beverages. The English, and their colonies, at the head of the one class, have chosen tea as the principal drink, with whom it has become a necessary of life; with the other class, including the French and Germans, the use of tea is an acquired taste, and remains a more conventional practice, which is only of importance to society amongst the higher, but has not penetrated into the domestic circle of the poorer classes of the community.

COFFEE.

In France and Germany the custom of the East has been followed, and coffee has become one of the chief necessaries of life amongst the people.* In consequence of this, it has risen in importance as an article of commerce, and increased the dependence of the northern consumers upon the coffee-producers of the East. These were originally only Egypt and Arabia; but after its consumption in Europe had become almost universal, all the states made a point of extending its cultivation to their colonies. From that time coffee-plantations sprung up in the West and East Indies, and in the Brazils, and it is imported equally from both sources. The coffee that is brought into commerce is the seed of the *Coffea Arabica*, a shrub belonging to the family of the *Rubiaceæ*, which reaches the height of 30 feet, when allowed to grow, but is usually cut down to the ordinary height of a man, to increase the crop of fruit. The fruit is a two-seeded berry, similar in appearance and colour to a small cherry; each berry contains two coffee-beans, in a fleshy or parchment-like integument. As the fruit does not all ripen at the same time, one crop requires several gatherings; the fleshy part of the fruit, which contains a considerable quantity of sugar, is separated partly by

* In 1840, the amount consumed in the States of the German League was 2 lbs. 5½ ozs. per head.

mechanical agency, and partly by fermentation. The fresh, ripe berries are pressed between rollers, and the thick juice allowed to run through sieves, in order to separate the beans by softening, and afterwards to clean them by washing with water, and subsequently to dry them. All that then remains to be done is to separate the outer skin from the berries, by crushing them under a heavy wooden wheel, and to winnow the chaff by a fan, as is practised with ordinary grain. In Venezuela, however, the plan followed is different, the berries are there spread out upon hurdles in the sun, where they undergo the vinous fermentation, from fourteen to twenty days, and then dry. The beans are freed from the skins by a mill in two operations, and from the chaff by winnowing.

The use of coffee dates, in Arabia, from the end of the fifteenth century: it was first introduced into Paris in the year 1669, and the first coffee-house was opened by Armenier, at St. Germain, in 1672. Although a single tree may bear as much as 20 lbs., yet in Venezuela 1.8 lb. is the average. An acre may be planted (= ¼ hectare) with 2560 plants, and yields, therefore, an annual crop of 1100 lbs. of dry beans.

The varieties of coffee are distinguished by the colour and size of the beans.

Arabian or Mocha coffee is small, and dark yellow. Java and East India (Malabar) is larger, and paler yellow. Ceylon resembles more that of the West Indies (Jamaica, Berbice, Demerara, Dominica, Barbadoes), which as well as the Brazilian has a blueish or greenish-grey tint.

Chemical constitution.—The examination of coffee has led to interesting results, although they are still defective in pointing out the quantitative composition of the berry.

The following is a comparative analysis of raw and roasted Martinico coffee, made by Schräder:

RAW COFFEE.

Peculiar coffee principle . . .	17.58
Gummy and mucilaginous extract .	3.64
Extractive	0.62
Resin	0.41
Fatty oil	0.52
Solid residue	66.66
Loss (water ?)	10.57
	100.00

ROASTED COFFEE.

Coffee principle	12.50
Extractive	4.80
Gum and mucilage	10.42
Oil and resin	2.08
Solid residue	68.75
Loss	1.45
	100.00

The tissue of the beans is formed of a horny mass, which yields the same product as woody-fibre by dry distillation (acetic acid, &c.), but affords neither sugar with powerful acids, nor a similar physical reaction, and its elementary composition is also different. This kind of vegetable fibre belongs rather to the species of woody incrustations, and encloses in coffee a series of substances, the most important of which is as follows. Robiquet discovered 10 per cent of fat in the coffee-bean,—a quantity which in Mocha coffee rises to 13 per cent. Rochleder found this fat to be a mixture of the compounds of glyceryl, with oleic and palmitic acids. The fat is itself inodorous, and contains, as do the beans, the peculiar odour of coffee, from a very minute quantity of a volatile oil, of an orange-yellow colour, which distils at a temperature of 72° C. (162° F.) It has not been clearly ascertained whether this aroma is contained in the fresh bean, or is first produced by roasting.

Caffeic acid.—Under the appellation *caffeic acid*, Pfaff and others, particularly Rochleder, have described a substance, consisting of $C_{16} H_{14} O_6 + 2 H_2 O$, and combined, as it would appear, with potash, lime, and perhaps with other bases. In this state the caffeic acid passes into the water with which the coffee is boiled. It is most nearly allied to the varieties of tannic acid, evolves the smell of coffee roasted at 180° C. = 356° F., and is changed into another acid, which remains in combination with bases when these are present. This acid being easily soluble in water, communicates to it an astringent, but not bitter taste; it attracts oxygen from the air, combining with it with avidity, and its salts, with baryta and lime, become green by this change.

Caffeine.—The substance known under this name was first separated by Runge, in the year 1820, and to this, as the active

principle, the peculiar properties of coffee are correctly ascribed. Jobet afterwards proved that caffeine and theine were identical :*

Theine = 50.1 Carb. + 29.0 Nitrog. + 5.2 Hydrog. + 15.7 Oxyg.
Caffeine = 49.8 „ + 28.8 „ + 5.1 „ + 16.2 „

Unfortunately there are no sufficiently accurate determinations of the amount of caffeine in the beans; for the statement of Pfaff, that the fresh beans only contain $\frac{1}{300}$, is probably much too small a quantity, while Payen has found five times as much, and Robiquet, from the same quantity, up to $\frac{1}{100}$ in roasted coffee.

Casein.—When the fresh, or roasted beans, are extracted with water, a small quantity of another nitrogenous substance is dissolved, which Rochleder identified with that from the leguminous fruits, it consists of legumin with a trace of albumen. A much larger portion remains in the exhausted beans, in combination with lime, of which coffee contains a considerable quantity. If some carbonate of soda be added to the water, nearly the whole of the legumin is taken into solution. When coffee-beans are drenched with water, a decomposition of the legumin soon appears, and in consequence of the sugar contained in the beans, is quickly followed by vinous fermentation. It is possible, that the latter may have passed from the fleshy portion of the fruit into the bean.

With these substances, which were the first detected and distinguished, other mineral ingredients are associated in coffee, which remain, on incineration, in the ash (3.19 to 5 per cent), and consist of carbonate and sulphate of potash, chloride of potassium, carbonate and phosphate of lime, magnesia, oxides of iron and manganese.

The following is the composition of the ash of coffee, according to Levi :

Potash	50.94
Soda	14.76
Lime	4.33
Magnesia	10.90
Oxide of iron	0.66
Phosphoric acid	13.59
Sulphuric acid	trace
Chlorine	1.22
Silicic acid	3.58
	99.98

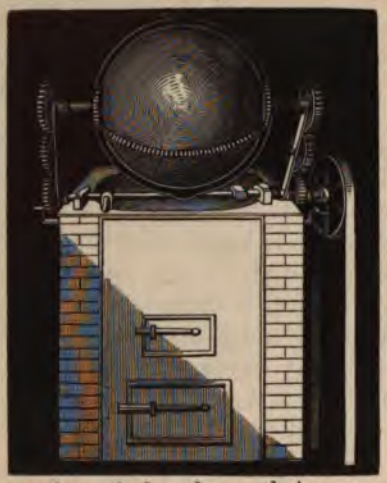
* The numbers are the immediate result of analysis.

Preparation. Roasting.—There are two objections to the use of fresh coffee-beans; firstly, a somewhat bitter taste, and the difficulty attending the pulverization of the beans, which is absolutely necessary, in order that they may be thoroughly exhausted by water. Both are remedied in a very efficient manner by roasting, or by heating and decomposing the coffee up to a certain point. The beans are thus rendered dry and brittle, at the same time that their taste is improved, and their ingredients become more soluble. Although nothing certain is known respecting the chemical changes that have been thus effected, yet so much is ascertained, that it is chiefly the caffeic acid which is affected, and which, with the evolution of an agreeable empyreumatic odour, is converted into another acid. According to Payen, the portion of caffeine previously in combination with it is thus set free. Sugar is similarly decomposed under like circumstances, and converted into brown burnt sugar, or Caramel. Too high a temperature, at which the beans are charred, would of course vitiate the whole object of the process, the empyreumatic products from the vegetable fibre and the legumin, having the disagreeable odour of burnt horn would be evolved, while the real aroma would escape, the sugar and the fat would be destroyed, and all the caffein volatilized. The latter is always partially lost, as is proved by the difference in the quantities contained in fresh and roasted coffee.* Fresh coffee yields an astringent infusion, which, without the agreeable taste, has a more powerful action on the nerves than when roasted. Although the temperature for roasting is easily regulated, it is nearly always exceeded in practice, although not to such an extent as to give rise to the products enumerated above. The far greater perfection to which the French have brought the preparation of coffee than the Germans, is due not only to their rejection of bad admixtures, but also in a greater degree to the art of properly roasting it. Caffein begins to sublime at a temperature of 385° C. (725° F.); the decomposition of caffeic acid, and of the sugar, &c., obviously begins, from the darkening of the colour, at a temperature below 200° C. (392° F.), and this can be carried on in the quickest possible manner, and at a very uniform temperature of about 200° C., in closed roasters, which retain the aroma as much as possible. Horizontal, roller-shaped drums answer best, which can be rotated over the open fire.

The best form of coffee-roaster appears to be that of Mr. Law, and which he calls the globe roaster. It is shown in Fig. 31.

* *Vide* analysis, pp. 136, 137.

FIG. 31.



By very simple machinery, as shown in the drawing, a metal globe containing the berries is subjected to two simultaneous rotatory motions, the one at right angles to the other, the whole being surrounded by a cast metal casing, and thus the direct heat of the fire being exchanged for the more regular and constant temperature of heated air; the coffee berries are uniformly roasted at all parts. All may be under-done, or all overdone in this machine, but the more usual fault of one portion of the charge being over-done, while another portion is insufficiently roasted, is rendered quite impossible.

Fresh roasted coffee should be allowed to cool in close vessels during which a quantity of moisture is deposited on the sides of the vessels. All, however, are not aware that the quality of the coffee is much improved when the beans are washed for a few minutes in cold water and dried in cloths before being roasted. The coloured appearance of the wash-water, as well as the fact that during the preparation of the coffee, its transport and in the warehouse, much dirt is collected about it, and indeed, often fraudulently mixed to give it colour, sufficiently account for this. A loss of weight is of course sustained by the coffee in roasting, but it gains in bulk at the same time, in proportion to the degree of heat applied.

Payen found in 100 parts dried:

	Martinique.	Bourbon.	Mocha.	
Amount of nitrogen .	2.46	2.54	2.49	The coffee from Martinique lost 11.58 per cent of its weight in drying.
Ash	5.00	4.66	7.84	

Coffee from Martinique afforded:

	Unroasted.	Slightly reddened.	Chestnut-brown.	Brown.
Loss in roasting . .	—	15 per cent	20 per cent	25 per cent
Increase in bulk . .	—	1.3 times	1.53 times	—
Extract	40.0 per cent	37.0 per cent	37.1 per cent	39.25 ,,
Insoluble residue . .	48.5 ,,	—	—	—

By roasting until a loss of 25 per cent resulted, a product was

obtained which still retained 2 per cent of water, but the same amount of nitrogen (2.41) as the dry coffee. With reference to the actual constituents, therefore, 100 parts of dry coffee, with 2.4 per cent of nitrogen yield 75 parts of roasted coffee, with 1.8 per cent of nitrogen, so that 0.66 per cent of nitrogen, or a similar quantity of nitrogenous matter is lost in roasting. The numerous observations of others correspond with these results; for instance, those of Dausse, who states that Martinique coffee affords the most agreeable beverage when roasted so as to lose 20 per cent of its weight, or when its colour is chestnut-brown; Bourbon coffee when roasted so as to lose 16 or 18 per cent, or when its colour is light bronze, and Mocha coffee when it has lost only about 14 or 15 per cent, or has become reddish-yellow. According to the same authority, infusions made at 80° C. (176° F.), as coffee is usually consumed, yielded with Martinique 31 per cent, with Bourbon 25, with Mocha 22 per cent of extract. Payen's results presuppose an entire exhaustion of the ground coffee by water, which is never carried out in practice. In order to make an experiment comparable with the others, Payen infused at once 100 parts of ground coffee with 1000 parts of water. The quantity of extract and the amount of nitrogen in the Martinique coffee were as follows:

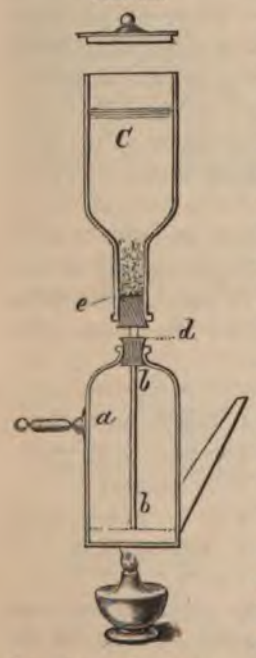
Degree of roasting.	Extract.	Nitrogen in 100 parts of extract.	Ash in 100 parts of extract.	Nitrogen in the extract from 100 parts of coffee:	Ash in the extract from 100 parts of coffee:
Light red . . .	25	—	—	—	—
Chestnut-brown .	19	2.82	16.9	0.72	3.23
Brown	16	4.36	18.9	0.71	3.04

It follows that the beverage, as ordinarily prepared, contains only $\frac{3}{7}$ths of the nitrogenous matter (the nutritive matter) of the fresh bean, but $\frac{3}{5}$ths of the roasted, and that the mineral ingredients are nearly all present.

If the $2\frac{1}{2}$ per cent of nitrogen were equally divided between the nitrogenous ingredients, this would correspond with 4 per cent of caffein and 9 per cent of legumin. The latter remains almost entirely in the residuum, and is consumed like chocolate by Oriental nations, who do not confine themselves to the infusion. When the infusion contains, as in the above instance, for every 16 or 19 parts of extract, 0.7 parts of nitrogen, this would correspond with $2\frac{1}{2}$ parts of caffein, the trifling quantity of legumin not being taken into calculation.

Boiling.—The constituents of coffee and their reactions clearly indicate that to boil it upon the old plan cannot be judicious, but must always cause the loss of the greater part of the aroma. The better mode of preparing it is that of infusion, and it mainly depends upon good manipulation whether, with the same proportions of water and coffee, an equally strong infusion with the same quantity of soluble matter is obtained as by boiling. The contrivances by which the best results are obtained are well illustrated by the drawing (Fig. 32). The glass tube *bb* is fitted tightly into the neck of the flask *C* by means of a cork, upon which a pierced drainer is placed. The tube can at any time be made air-tight in the boiling vessel by means of the cork *d*. The water is poured into *a*, the ground coffee being placed in *C* which then lies upon the drainer. When the water is boiled by means of the spirit lamp, the enclosed steam pressing upon it, forces it to rise through *bb* into *C*, passing on its way through the ground coffee. When the lower end of *bb* is thus left open, the air and the steam which is evolved from the remainder of the water, find their way out through *C*, and soon bring the contents of this vessel to 100° C. (212° F.), the steam condensing in the first instance, but afterwards passing through unchanged. This actual boiling is allowed to continue for a few minutes, and the lamp is then removed. The steam condenses in *a*, and produces a vacuous space, the atmospheric air consequently forces the water with considerable pressure through the coffee, which in the meantime has settled down on the seive *e*, through the tube *bb*, to *a* where it collects as a strong infusion. The coffee forms a narrow and tall column in the neck of *C* above *e*, which is consequently extracted rapidly with boiling water under a high pressure. The air rushing through after the infusion has passed, forces out what remains in the pores. Attention must be paid to the size of the powder of the coffee: when the strongest possible infusion is desired from a given quantity of the bean, one-fourth more extract is obtained from coffee ground to the consistence of flour, than from

FIG. 32.



the ordinary coarse powder; the filter must of course be adapted to this powder, in order that the liquid may be clear.

Substitutes.—The high price and large consumption of coffee, soon led to the discovery of cheap substitutes. Although it is certain that no substances have yet been discovered which can replace coffee in the true sense of the word, yet—without enumerating a host of others—we may mention, dried yellow turnips, which are employed almost universally amongst the lower classes in Germany, and the chicory root which is so very extensively used, that 10,000 cwts. are annually manufactured in Berlin, and 20,000 cwts. more in Halberstadt and Brunswick. These facts indicate a great degree of poverty and ignorance, a self-deception being practised which confounds the colour with the real substance. It can hardly be doubted that with the dissemination of correct knowledge respecting the quality of coffee, the chicory manufacture will soon disappear. Nothing has yet been discovered in either chicory or turnips, that can in any way replace the caffeine in coffee, they yield a deeply coloured infusion, and inattentive persons are not capable of distinguishing between "black" and "strong" coffee.

In England, according to the Report of the Analytical Sanitary Commission, published in the 'Lancet,' chicory, and other substances, to a small extent, form not less than one-third of the entire amount of the mixture sold as pure coffee. The duty collected upon coffee was, in 1850, £67,000 less than in 1849, notwithstanding the increase of population, and the absence of other causes to diminish the consumption. The other substances employed for adulteration are roasted corn, beans, potato, and burnt sugar.

CHOCOLATE.

Although chocolate is not a daily necessary like tea and coffee, yet the large quantity consumed entitles it to some notice. Chocolate is made from the beans of *Theobroma cacao*, a small tree of the Malva-family, indigenous to tropical America, and the West Indian Islands, which bears a very small flower, not 2 lines in diameter, and a disproportionally sized gourd-like fruit, which is 4 inches thick and 10 inches long. It contains in a reddish-white agreeably tasted pulp, 25 to 40 kernels or cacao beans, each covered with a skin, with which they are brought into commerce. When the fruit is ripe, the beans are separated from the flesh and heaped up in pits or ditches covered with boards, where they are left for some days under frequent inspection. A sort of fermentation

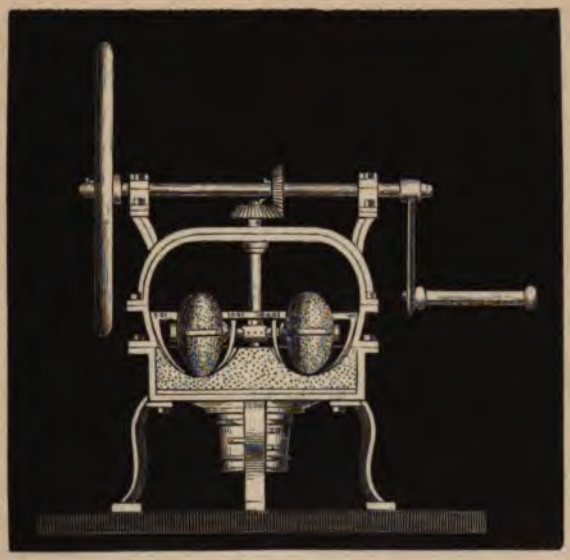
is thus set up in them which removes a good deal of their bitterness and renders them darker in colour; they are subsequently dried in the sun. There are a great many varieties; that from Caraccas is the best, and the West Indian the worst. The beans of cacao have not been thoroughly examined; they are only known to contain a peculiar mild fat, the cacao butter, to the amount of 43 per cent according to Boussingault, and 53 per cent according to Lampadius. Both experimenters found a considerable quantity of albumen, a kind of tannic acid, and some starch among the more remarkable ingredients. Lampadius' analysis of the cacao of the East Indies does not include the husk, which forms about 15 per cent of the weight of the beans. It is as follows:

Cacao butter	53.10
Brown and albuminous matter, containing the aromatic principle of cacao . .	16.70
Starch	10.91
Gummy matter	7.75
Vegetable fibre	0.90
Red colouring matter	2.01
Water	8.63
	100.00

Woskresensky has proved that the beans also contain a peculiar ingredient, similar to caffeine, which he called *theobromine*. But this substance which is still imperfectly known, differs in composition (C_{14} H_{16} N_8 O_4, Will.) from the others, containing more nitrogen (35 per cent), although in taste it exhibits a remarkable resemblance to caffeine. It cannot be sublimed without decomposition.

In preparing chocolate the cacao beans are roasted in a cylinder similar to those employed for roasting coffee. In this operation the aroma is developed, the bitterness diminished, and the beans are rendered fragile. They are broken under a wooden roller, and winnowed to remove the husk entirely. They may then be reduced to a soft paste in a machine like that shown in Fig. 33, consisting of an annular trough of granite, in which two spheroidal granite millstones are turned by machinery, with knives attached, to return the ingredients under the rubbing surface. An equal weight of sugar is here added to the paste, which is finally rendered quite smooth by being ground under horizontal rollers on a plate of iron, heated to about 130° or 140° F.

FIG. 33.



Preparation.—The preparation of the cacao consists in roasting, peeling and grating the pealed beans in a warmed rasping apparatus or chocolate machine. The flour of the seeds forms with the liquid fat (melting at 40° C.=104° F.) a kind of paste which congeals to a solid cake in the moulds.

Cacao is now often ground without the addition of sugar, and the husk, which contains no fatty matter, but does not yield a disagreeable infusion when boiled for a length of time with water, is sold to the poorer classes as a substitute for chocolate.

General considerations.—There are at least 713,000 cwts. of tea consumed in Europe and America, and 61,000 cwts. of coffee in the commercial union; in England and America the use of tea is as much a daily necessary of life to the humblest peasant as to the richest of the aristocracy; while in Germany the people cling to the use of coffee the more tenaciously, the poorer they become, and the smallest amount of wages is always portioned out into a fraction for coffee, another for bread, and another for potatoes; with such facts staring us in the face, the assertion can hardly be justified, that the use of coffee and tea is something unessential, an outward want, a mere matter of habit. On the contrary

from various reasons, it appears very probable that the instinct of the people, perceiving certain specific deficiencies in the ordinary food, which cannot be well made up by larger quantities, has found in these products the very substance to supply that deficiency and clings tenaciously to it, as that which is required to complete and render its daily bread most nutritious. While the choice has fallen solely upon tea and coffee, from among a great variety of vegetables, scientific inquiries have proved, that notwithstanding the variations in the origin and locality, in the botanical position, of the mother plant, the organs which are consumed (the leaf in tea and the seed in coffee) exhibit a remarkable similarity in composition, as the foundation of that choice. The characteristic ingredient in both, theine or caffeine is accompanied by an acid allied to tannic acid and by vegetable casein; both exhibit a large quantity of nitrogen in their composition, and both have the same specific effect upon the system. When the application of Paraguay tea, and its chemical composition are also included in the observation, it must strike the most inattentive as an astonishing fact, that instinct has anticipated science in applying the substance theine to its destined uses.

The great increase in the amounts of tea, coffee, and cocoa, consumed in this country within the last few years, as shown by the revenue returns, is far more than can be accounted for by mere increase of population, and the corresponding diminution in the consumption of spirituous liquors of all kinds, clearly indicates that the tastes of the great mass of the people, whether influenced by economy or sanatory considerations, incline in favour of the former beverages.

The following table clearly proves the fact of this increase:

Years ending January 5th.	Coffee.	Tea.	Cocoa.	British spirits.	Beer.	Wine.
	lbs.	lbs.	lbs.	gallons.	barrels.	gallons.
1836	23,295,046	36,574,004	1,084,170	24,710,208	16,330,010	6,420,342
1840	26,789,945	35,127,287	1,606,800	25,190,843	15,883,311	7,000,486
1845	31,352,382	41,363,770	2,589,977	20,608,525	14,624,854	6,838,684
1850	34,431,074	50,024,688	3,233,372	22,962,012	15,243,681	6,247,689
If the population of the year ending January 5th, 1850, had drank the same quantity per head as the population of the year ending January 5th, 1836, (the population having increased 40,000 in the interval), the quantity consumed in the year 1850 would have been	27,268,189	42,444,291	1,258,067	28,673,638	18,949,286	7,450,142

Had the population of 1849 to 1850 drank of coffee, tea, and

cocoa, the same quantity per head as the population of 1835—6, the increase in the consumption of these articles would have been only 10,000,000 lbs., whereas it has been nearly 27,000,000 lbs., or considerably more than one-third; and had the population of 1849—50 drank of spirits, wine, and beer, the same quantity per head as the population of 1835—6 did, the increase in the consumption of these articles would have been 100,000,000 gallons; whereas, there has been a decrease of 40,000,000 gallons; showing the actual difference, taking the increase of population into account, to be upwards of 140,000,000 gallons, or more than a fifth part of the entire quantity consumed in 1836.

The specific action of theine in the process of nutrition is still a problem for future investigation. The connection between theine, and the production of bile which was formerly supposed, has lost all its probability and interest, since the discovery of the large amount of sulphur contained in taurin. On the other hand, the recent discoveries with reference to the nature of flesh, and its juices, afford an interesting point of comparison, which possibly indicates the way towards the solution of the question. A certain proportion of creatin and creatinine is an essential characteristic, as has been shown above, of the juice of flesh, and distinguishes it and its action from that of gelatin soup, and other substitutes. Creatinine, creatin, theine, and theobromine, belong to one and the same class of chemical compounds, which, like quinine, communicate their characteristic properties to a series of vegetable principles and medicines. The kind of action they exert upon the system is very different from the function of food. The latter is only effective when the amount consumed corresponds ounce for ounce with the amount of substance wasted by the body in performing its several functions. The organic bases on the contrary, to which these bodies are allied, exert an action which is totally disproportioned to their quantity. It would, therefore, appear as if a third condition were essential to nutrition, as well as those necessary to the formation of blood, and the production of heat; whether this is connected with some direct action upon the nerves, or upon some other organ, must be left to the physiologist to decide. So much, however, is certain that the food of man is least nutritious when it consists for the greater part of potatoes, and that those countries which have furnished this defective food, have it also in their power to supply us in some measure with a remedy in tea, coffee, and cacao.

TOBACCO.

Although tobacco cannot be called a species of food, still the present will be found to be the most convenient place to notice this product.

Origin.—The plants which afford the material for smoking form the species *Nicotiana,* of the family of the *Solaneæ,* among which the *Nicotiana tabacum* more especially, and *Nicotiana rustica, glutinosa, macrophylla,* &c. are, occasionally, cultivated. The Spaniards were the first to discover the habit of smoking tobacco as practised by the natives of the island of Cuba;* and although the practice was totally foreign to the Germanic, Teutonic, and Romanic races, it has nevertheless in the course of time become deeply rooted in Europe, and is gaining ground in spite of etiquette, education and police regulations. With the extension of the habit of smoking, the cultivation of the tobacco plant has likewise increased. It took its rise in Portugal, about the year 1558, and was introduced from thence into France and Spain, about the time of Catherine de Medicis, by J. Nicot, (hence the name Nicotiana). Smoking was introduced from Virginia into England, and Charles V. brought the practice from Spain to the Germans. Tobacco has been grown in the Mark of Brandenburg, since the year 1676, and in the Pfalz since 1697. The effect of soil and climate, and the mode of cultivation is so very great upon the quality of the tobacco leaves, that in this respect the vine is the only plant to which it can be compared. Thus in three or four years, the tobacco grown in Germany from American seed, acquires an aroma perfectly distinct from that of fine tobacco, and this it retains pertinaceously, and is too well known to most persons under the appellation of "*Knellern.*" Too rapid and luxuriant growth spoils the flavour of the leaf, which, on the contrary is heightened by pruning.

Nicotine.—Among the constituents of the tobacco-leaf, *Nicotine* is the most characteristic. This is a volatile vegetable alkaloid (C_{10} H_{16} N_2), belonging, therefore, to a class of nitrogenous organic substances, which are, for the most part, gifted with a very energetic and remarkable action on the animal system. Pure nicotine is a colourless, oily liquid, possessing a slight smell of tobacco, which, when the liquid is heated, or mixed with ammonia, becomes very intense and biting, it has also a sharp irritating

* It is not improbable that the use of tobacco in Asia, particularly in China, is of more ancient date than the discovery of America.

taste, a few drops acting as a poison upon small animals. The existence of a substance described under the name of nicotianine, which separates in extremely minute quantity in distilling water over the tobacco-leaves, and to which the real source of the odour of tobacco is ascribed, appears still rather problematical.

The quantity of nicotine has been estimated by Posselt and Reimann in the fresh leaves at $\frac{6}{10000}$, by Boutron in commercial leaves at $\frac{53}{10000}$ to $\frac{100}{10000}$, according to the kind, and it does not appear to stand in direct proportion with the quality of the tobacco. Schlösing* estimated the amount of nicotine in the French and American tobaccos as follows:

		Percentage in the dry leaves.			Percentage in the dry leaves.
Department	Lot	7.96	Department	Elsass	3.12
„	Lot-Garonne	7.34	Virginia		6.87
„	Nord	6.58	Kentucky		6.09
„	Ille-Vilaine	6.29	Maryland		2.29
„	Channel of Calais	4.94	Havanna	less than	2

Besides nicotine, tobacco contains albumen and a gluten-like substance, and to these may be added the non-nitrogenous constituents—gum, resin, and particularly two organic acids, the malic and citric. The leaves of tobacco leave a large amount of ash when incinerated.

The following table shows the amount of ash in the Hungarian tobacco-leaf, as well as its composition, according to Will and Fresenius:

	Debreczin.			Bannat.	Mean of 4 preceding.	Fünfkirchen.				Mean of 4 preceding.
Potash	29.08	30.67	27.88	18.20	26.46	11.21	8.20	19.55	9.68	12.14
Soda	2.26	..	..	..	0.56	..	..	0.27	..	0.07
Lime	27.67	24.79	31.16	27.86	27.87	47.03	42 77	44.49	49 28	45 90
Magnesia	7.22	8.57	7.31	15.73	9.72	12.77	13.93	11.07	14 58	13.09
Chloride of sodium	0 91	5.95	9.34	11.41	6.91	2.58	3.22	3.54	4.61	3.49
Chloride of potassium	..	..	4.90	3.92	2.21	2.97	8.53	..	4 44	3.98
Phosphate of iron	8.78	6.03	6.39	6.80	7.00	6.30	6.07	4 34	5.19	5.48
Phosphate of lime	..	..	..	..	..	..	..	5.97	..	1.49
Sulphate of lime	6.43	5.60	6.43	10.11	7.14	5.11	7.96	5.63	6.68	6.35
Silica	17.65	18.39	6.59	5.97	12.13	12.03	9.32	5.14	5.54	8.01
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Percentage of ash	18.90	22.20	24.50	19.80	21.28	27.36	23.00	21.08	23.28	23.68

Principles of manufacture.—Good tobacco should evolve an agreeable odour when smoked, and produce no biting sensation on the tongue or throat, or that peculiar action on the nerves in an

* A pupil of the Royal Tobacco Manufactory at Paris.

excessive degree, which consists in an unpleasant excitement and dulness in the head, and is attributed to its being *too strong*. These qualities consequently require that the characteristic ingredient, the nicotine, should be as little active as possible, and to this constituent the enjoyment of the smoker cannot, therefore, be ascribed. The leaf in its natural state is not adapted for consumption for these reasons, and also on account of the gluten-like principle, which, like all nitrogenous matters, evolves a very disagreeable odour of burnt horn when consumed. In preparing tobacco for use there is, therefore, a double object to be effected, first, to shape the leaf conveniently for smoking, and second, by some chemical process to prevent, to a certain extent, the nitrogenous substances and the nicotine from being over active, and at the same time to induce an agreeable aroma. The chemical process upon which this preparation depends is essentially a fermentative process, partly carried on in the leaves prior to the harvest and to their exportation, and partly as an operation of the home-manufacture—it is a spontaneous decomposition commenced by the nitrogenous ingredients in the moist leaves when thrown into heaps, which assists the manufacturer not only as a decomposing, but likewise as a producing agent, inasmuch as it gives rise to the production of volatile and powerfully aromatic substances. When this fermentative process is carried out in the colonies, the plants are hung up to dry, and then during damp weather are allowed to sweat or heat in heaps for a week or two, according to the state of the weather, care being taken that they do not become too hot, which would induce putrefactive decomposition. Often, however, they are exported to this country without any previous fermentation, and even here no direct fermentation is induced in them, the wetting with water being only intended to make them pliant, and enable the tendril to be removed more easily. The quality of the tobacco, as far as it lies in the power of the manufacturer, is entirely dependent upon the management of this fermentation, and several precautions taken during the operations are all destined to influence the process. Thus, the addition of salt to the moistening water, moderates the fermentation, while saccharine matters, as the extract from figs and liquorice-root, &c., promote it; all these constitute, with the moistening water, the so-called "*sauce*."* The substances

* No additions of this kind are now permitted by the Excise regulations in this country.

evolved during fermentation, which are so intimately connected with the odour of manufactured tobacco and its improvement, have been not improperly compared to the aroma of wines.

A clear and distinct view of the objects and processes concerned in the manufacture of tobacco, presupposes an accurate comparison of the manufactured article with the natural leaf, and an attentive study of the phenomena attending the drying and fermentative processes. This, however, science is not in a condition to supply, and the description of the manufacture must consequently be confined to a short indication of the mode of operation.

Manufacture of tobacco for smoking.—Although the leaves are sorted, according to their position on the stem, and their quality at the time of harvest, after which they are hung upon strings and dried, in order to be sent to market, yet the first operation of the manufacturer is to re-sort them, as two principal objects are thereby gained, namely, the uniformity of his produce, and his own profit. The tobacco-leaves are then moistened, either with the sauce (the composition of which is often kept secret), or with salt water, or even pure water, and heaped together, in order to undergo a very slight fermentation, at the close of which they are sufficiently moist and soft to admit of the chief ribs, or leaf-stalks and veins being removed, which are woody and poor, and deteriorate the taste. The different kinds are then mixed in proportions to suit the market, and submitted to a second fermentation, after which they are cut up.* Special machines are in use for cutting tobacco, in which the leaves are forced forward to meet a knife, that has an upward and downward motion. The cut tobacco acquires the curly appearance by being dried upon warmed slabs or hot plates, after which it is spread out to allow the steam to evaporate, and is then in a fit state for packing in paper.

The manufacture of tobacco in England is confined to the mechanical operations of cutting and drying. The principal kinds which are sold in the shops differ only in the quality of the leaf, and in the form given them by the manufacturer, all are precisely similar as far as the chemical treatment is concerned. For *shag* tobacco and *returns*, as also for cigars, the mid-rib or vein of the leaf is removed prior to cutting. In *bird's-eye* the stalk or vein is left entire. The *twist* or *roll* tobacco is spun from the finest leaf, or Virginia tobacco, and subsequently submitted to pressure in balls

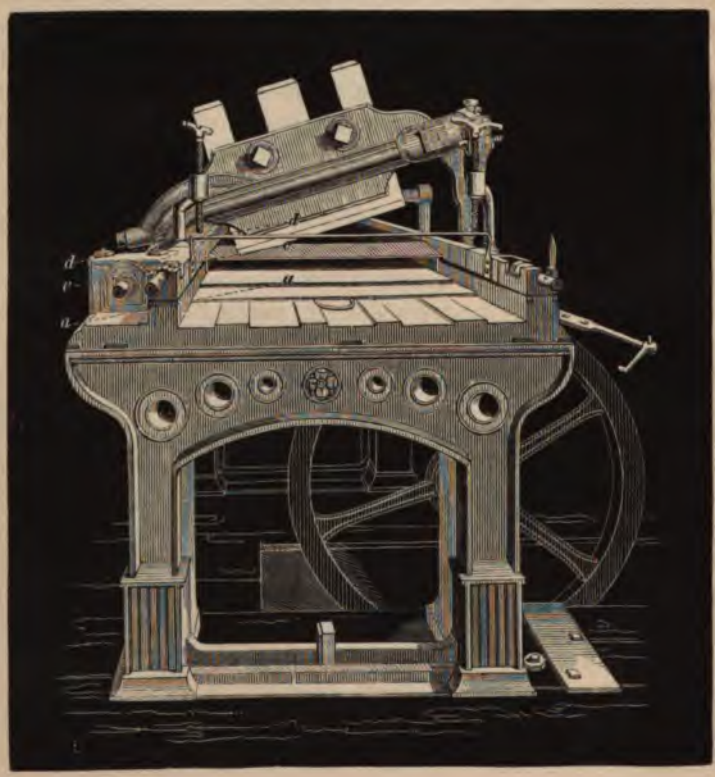
* The second fermentation must be peculiar to Germany, as no such practice is adopted in England or France.

tightly tied up with cord. *Cavendish* is pressed in flat cakes, but prepared from the same raw material.

The first operation on removing the leaf from the hogsheads in which it is imported, consists in moistening it with water in small quantities at a time, not with a view of inducing any fermentation or chemical change, but simply to render it soft and pliant, that the stalk or mid-rib may be easily torn away from the remainder of the leaf, an operation which is performed by women and boys with the aid of a knife. The portions of leaf thus deprived of stalk, as required for shag and returns, as also for cigars—this operation not being requisite for bird's-eye—are arranged one upon the other in boxes of about 18 inches or 2 feet square, and when a sufficient quantity has been thus arranged, the whole heap is submitted to a powerful pressure.

On leaving the press, it has the form of a square cake about 2 or 3 inches in thickness, and is placed upon the cutting-board *a*

FIG. 34.



of the cutting machine, shown in Fig. 34.* The board with the cake of leaf-tobacco is placed under the plate or keeper of the machine, and slightly pressed down by screws at *c*, but not so strongly as to prevent its being forced gradually forward towards the knife by a fine screw, which works at the back of the machine, and could not be shown in the drawing. In front of the plate, containing the tobacco, a sharp knife *d* is moved in an upward and downward slanting direction, making from twenty to forty cuts per second, in close contact with the edge of the plate, and the tobacco being simultaneously forced forward, the whole cake is cut into fine shreds in the course of about eight or ten minutes. The fineness of the shreds is determined by a cog-wheel acting on the thread of the screw, which presses the cake of tobacco onwards. The cutting-board on which the cake is placed, is constructed of such length, that when nearly the entire cake of tobacco has been cut, it presses against a spring in front, which at the right moment throws the machine out of gear, stops the knife, and prevents its edge coming in contact with the iron of the board which would injure it.

The cut tobacco has now only to be opened and dried to render it fit for sale; this is done upon hot plates heated by steam or fire, upon which the cut tobacco is spread out in thin layers, until the requisite amount of water has been driven out of it, and the shreds or hair-like cuts are properly opened and separated from each other. In some manufactories, it is exposed, previously to drying, to a current of steam, with a view of more thoroughly opening out the fibres or shreds, and preventing their adhering together.

The law and Excise regulations in England allow nothing but pure water to be added to the raw material in the manufacture of tobacco, but cases of fraud are very frequent, and various substances have been employed as adulterations. The following are the chief of these, according to the researches of Mr. Phillips, of the Inland Revenue Office, whose exertions to protect the honest manufacturer from these fraudulent practices, have been unremitting and eminently successful: liquorice, sugar, molasses, starch (chiefly potato), dextrine, gum, catechu, peat and wood ground, various earthy mixtures, sand, alkaline and earthy salts, rhubarb, burdock, coltsfoot, and various other leaves.

The machine used for cutting tobacco for smoking, at the Royal Manufactory of France, is shown in Figs. 35 and 36. Fig. 35 is an

* For the drawing of Fig. 34, we are indebted to the kindness of Mr. Fryer, of Smithfield Bars.

end view, and Fig. 36 a longitudinal section. The motion is communicated by belts to a pulley *B*, which moves a beam *E*, to the other end of which is attached the knife *G*. The leaves of tobacco are moved forward from a box *Y* on to an endless chain, which carries it between the tables *V*, where they are subjected to considerable pressure, by means of the rollers *O'*, N^2, and *P'*, *M'*, as they are presented to the action of the knife *G'*. This machine cuts about 2½ cwts. per hour. The other details, which only possess an interest for the engineer, are intended to regulate the motion, and maintain the machine in proper working order.

FIG. 35.

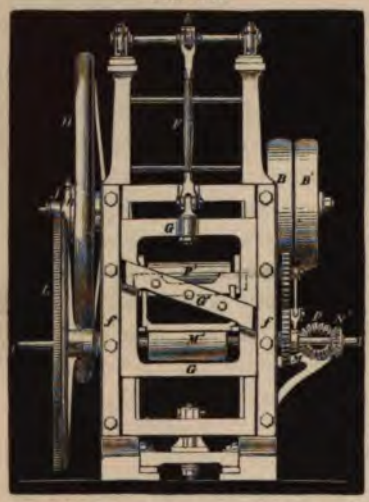
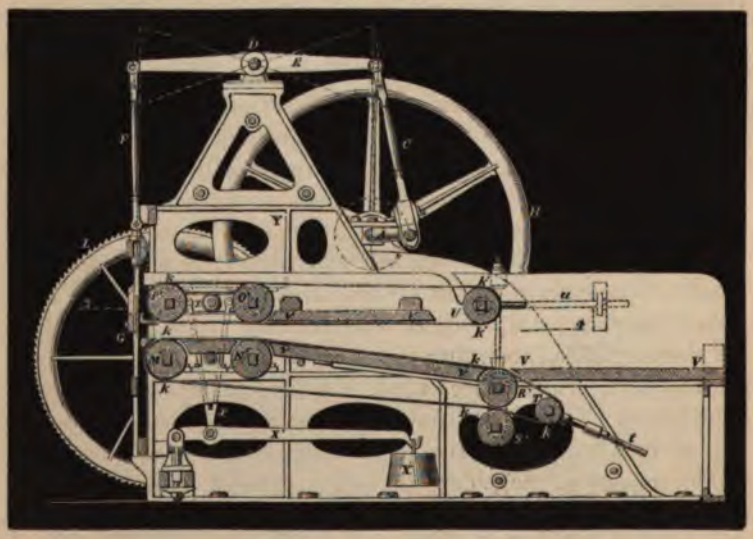


FIG. 36.



Some tobacco is brought into commerce in the form of rolls (Varinas), and left to the consumer to cut; this is produced by what is termed spinning. The leaves are sorted, the larger ones being set aside from the broken fragments and smaller leaves, the

former being used as an envelope for the latter. The manufacturer rolls the smaller parts and fragments in the larger leaves, forming a uniformly thick cord of any length, and this is wound in a spiral manner round a reel.

Cigars were first invented by the Spaniards, and of late years have superseded to a great extent the practice of smoking tobacco in pipes. A central mass of leaf is, in these, surrounded by a wrapping leaf in a spiral manner. They are all made by hand.

The amount of nicotine in smoking-tobacco is less by $\frac{1}{3}$ to $\frac{3}{4}$ than that contained in the raw leaf. As nicotine is much more easily volatilized with the vapour of ammonia than by itself, it is probable that this diminution of its quantity is due to the abundant evolution of ammonia during fermentation. The improvement in the flavour and quality of tobacco by keeping—which is certainly great—may possibly consist in a gradual continuation of this process, but nothing certain has been ascertained respecting it.

There are naturally innumerable deviations from the process described above, but the main features remain the same in all the modifications.

In smoking pipes or cigars, it is obvious that each layer of tobacco which is burning causes a dry distillation of the layer immediately adjoining it, in the direction of the draught, the products of which the smoker takes into his mouth simultaneously with the products of combustion. The products produced in smoking tobacco have been examined more accurately by Zeise, and interesting facts elicited, although there were none amongst them which threw any light upon the actual source of the enjoyment of smoking. A peculiar empyreumatic oil was discovered in the smoke from Porto Rico tobacco, a peculiar empyreumatic resin, ammonia, paraffin, some acetic acid (?), and what is most remarkable, a considerable quantity of butyric acid; in addition to these the ordinary gases, carbonic acid, carbonic oxide, and carburetted hydrogen. The absence of kreosot (which has been proved) explains why the smoke of tobacco does not irritate the trachea, and produce coughing, as is the case with wood smoke.

The amount of saltpetre, which is natural to all, more particularly Dutch tobacco, and is often artificially increased, facilitates the burning.

Manufacture of snuff.—The leaves intended for the production of snuff demand, during growth, a different treatment; they require powerful animal manure, while vegetable manure is better suited for smoking-tobacco. They are sorted and liquored

in a similar manner, but the sauce is specially adapted to the object in view; firstly, saccharine substances are added to it, as honey, must, &c., then salts, particularly ammoniacal salts and potashes, saltpetre, &c., and lastly perfumes, as violet-roots, Tonca-beans, and odoriferous oils. The salts of ammonia help to develop the odour of tobacco, the ammonia serving as a purveyor.* The liquored leaves are tied up in bundles like "*carrots*," in which state they are best preserved, they are then ground, "*rappeed*," or stamped to powder, and packed.

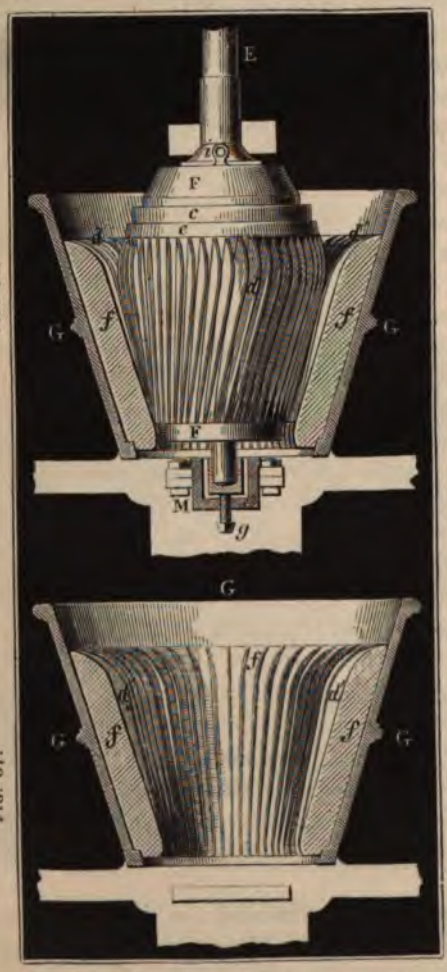


FIG. 38.

FIG. 37.

Figs. 37 and 38 are vertical sections of a mill for grinding tobacco into snuff, employed in the Royal Manufactory of France. The lower drawing shows the exterior cast-metal casing *G*, with its lining of thin iron blades *d*, which are kept in their position by wedges of wood *ff*. The upper drawing represents a portion of the same arrangement, and the grinder *F* made of cast-iron, to which the segments of wood are attached, and made tight by an iron collar *c*. These segments are notched for the purpose of fixing the blades *d'*, which are also secured by an iron ring *e*. Motion is communicated to the shaft *E*, and the peculiar action of the blades reduces any vegetable matter readily to powder, the distance

* Nothing but alkaline salts are allowed to be added to snuff by the Excise regulations in this country.

between the two sets of blades, which are ninety-six in number, being regulated by the screw *g*. The tobacco used for snuff in France is generally of a superior character to that employed for the same purpose in other countries. It is first cut up by means of an instrument in which several knife-blades are arranged upon a circular wheel that revolves, the tobacco being screwed upon an endless cloth to meet the revolving wheel.

After being cut up, the tobacco is heaped in great masses together in bins of oak wood, in a large chamber, for the purpose of fermenting, a pipe being introduced into the centre of the mass into which a thermometer is placed. It is well to mix a little tobacco already undergoing fermentation with the fresh leaves, in order to accelerate the process, which often lasts from nine to eleven months.

At the end of ten or fifteen weeks the temperature rises to 158° or 176°, large quantities of carbonate of ammonia and carbonate of nicotine being evolved, and the acid in the tobacco having entirely disappeared. It is essential that the air be excluded as much as possible, which would give rise to acetic fermentation, and the temperature must be watched, that the mass be not converted into humus. The whole is then ground in the mills. The powder is now sifted, grosser portions being returned to the mill. It is then again allowed to lie and ferment slowly for several months in wooden bins, in order to develop the aroma.

In England, tobacco is ground into snuff first under horizontal millstones to a coarse powder, and is then stamped in mullers of wood with an iron pestle, which gives it a particular kind of grain much prized as rappee. The stalks and leaf-veins are mixed with parts of the leaves in the fermenting heaps.

According to Schlösing, dry snuff contains 2.04 per cent of nicotine, partly in a free state, partly as a basic salt; $\frac{2}{3}$ of the quantity contained in the leaves is lost during the fermentation. The growth and manufacture of tobacco in France is a Government monopoly, and yielded in 1844 a clear profit to the revenue of 337 per cent, or 79,499,379 francs (= £3,179,975).

In England, the law allows no tobacco to be grown in the country, and the duty levied upon the raw colonial produce is 3*s*. 2*d*. per lb., or about 1100 per cent on the prime cost of the leaf. This duty yielded an average revenue in the years 1841,

1842 and 1843, of £3,835,105. The enormous duty offers an immense premium for smuggling, and the evidence brought before the House of Commons, proved that the tobacco consumed in the country exceeded in amount that upon which duty was levied by about one half, while adulteration was carried on to a very great extent.

The total extent of land on which tobacco is cultivated in the districts of the German commercial league, amounts to 20 square miles, and the consumption in the year 1842 amounted to 760,870 cwts., or $2\frac{3}{4}$ lbs. per head.

APPENDIX ON THE PRESERVATION OF FOOD.

Many kinds of food can only be obtained at certain seasons of the year, or they are better and cheaper at those seasons. Upon this account alone the necessity arises of storing and preserving them at one period, for use at another. In provisioning an army, however, the time the food has to be kept is much longer, and in exploring expeditions and sea-voyages the preservation of food becomes a vital question, where months and even years must often be passed over without fresh supplies of provisions.

The researches into the chemical nature of the varieties of food, have shown that their proximate constituents are among the most complicated or least simple of chemical combinations, and as such are prone to separate chemically into simpler forms of matter, or to be decomposed. The very constituents which render ordinary food nutritious, are themselves the causes of this want of stability, which generally takes the form of putrefaction.

Putrefaction, although apparently a spontaneous process, nevertheless always commences with an absorption of atmospheric oxygen, and is essentially an oxidizing process. But besides the access of oxygen, or air, as the prime mover, several other conditions must be fulfilled, in order to its full development; among these are the presence of moisture, a temperature some degrees above the freezing-point, and below 30° or 40° (86° or 104° F.) Infusoria are also great promoters of putrefaction, without exactly being direct cause.

All the methods and recipes for the preservation of food, have for their object the removal of one or other of these inducing

causes, and from this point of view they can be easily investigated, and their action understood. Nature herself often aids preservation, as in the case of dried fruits. Gluten, albumen, casein, have themselves a strong tendency to undergo putrefactive decay, but the natural moisture of grain, of the leguminous fruits, of nuts, &c., is much too insignificant in quantity to admit of decay taking place. Simple protection from moisture and change of air is, therefore, in these cases sufficient, when care is also taken to exclude insects. This latter object has led to the extensive use of blue vitriol for seeds.

Preservation at low temperatures.—All places situated below the surface of the earth, have a temperature common to the strata of earth themselves; this degree of temperature is very constant, the great heat of summer and the frost of winter being equally excluded, and is lower than the temperature at which putrefaction commences. Potatoes, juicy fruits, as apples and pears, can consequently be preserved for months in cellars, where the necessary warmth for inducing decay is not attained. Decay indeed, particularly in badly-constructed cellars, is rather postponed than prevented. For the same reasons, potatoes and turnips may be preserved in covered pits, &c. It must not be forgotten, that the low temperatures of these localities is much assisted by the vital principle in the fruits themselves, tending to preserve their power of germination. A sound potato is a living portion of a plant. The death of the potato, whether caused by frost, by fungi—as in the potato disease—or by mechanical injuries, inevitably induces putrefaction under conditions which would otherwise preserve the tuber. This is no doubt, also, the reason why food, such as meat, in which life has entirely ceased to exist, cannot be preserved for any length of time in cellars, and resists putrefaction only at an ice-cold temperature, at which, however, it may be kept for any length of time. The most striking instance of this fact was furnished by Pallas' discovery, of the antediluvian mammoth, in the ice of Siberia, with hair, flesh, &c., in every respect perfect, as if recently immured.

Preservation by removal of moisture—drying.—The simplest and easiest mode of preservation is that of drying, in the air, by exposure to the sun, or by artificial heat, and is easily applied to certain kinds of food, while with others it is attended with great difficulty. Nearly all fruit, as plums, pears, apples; vegetables, as cabbage, beans, may be preserved by kiln-drying. It scarcely

requires to be noticed that all such kinds of food are changed in their nature by the process of drying; either the albumen is coagulated, the sugar converted into caramel, the starch dissolved, or some other change of a like character is effected, and that a slight and moderated heat is best calculated to preserve the quality of the vegetables. Too much heat in the oven, or drying-chamber, produces a very bitter taste, caused by an excessive decomposition of the sugar. The heat of the sun and air at the season of the fruit harvest, is seldom sufficiently powerful to replace that of the kiln, or oven.

Meat is more difficult to preserve by drying, but affords, when thus preserved, a better food than by any of the other processes. The Indian tribes of North America who live by the chase, preserve the meat which they carry with them in the hunting season, by separating the fat from it, and drying the muscular portion, cut into thin slices, by exposure to the sun and air. The tough, dry meat, which is then incapable of putrefaction, is stamped firmly together, that it may occupy as little space as possible, so as to be easy of transport. In this state it is called *Pemmican*, and affords the largest amount of nutritive food in the smallest possible space; but the tedious method of preparing it is too great when required in large quantities, as for the provision of ships, to render the practice desirable in Europe. The drying goes on so slowly that putrefaction will ensue, unless great precautions are observed during the operation, and if large thick pieces are dried in this manner it is almost certain to ensue. Small pieces and strips of flesh, again, are not adapted to the mode of cooking in general use, and for these reasons, although often attempted, the drying of meat has never come into general use. A Frenchman of the name of Dizé, proposed to boil the meat for twenty-five or thirty minutes, and then to dry it in drying-houses upon hurdles, at a temperature of from 50° to 70° (122° to 158° F.) He found that raw meat lost:

In boiling	26.5 p. c. viz.	{	25.0 water 1.5 extract
In drying	28.0 „		
Total	54.5 p. c.		

It is consequently not quite dry, but the requisite quantity of water has been removed. The objection raised to this method is that boiled meat has lost in boiling a portion of its essential ingredients, and is consequently no longer so nutritive a food, as meat simply dried.

Salting.—This most usual method adopted for preserving meat, is not free from the same objections. Salting, is indeed only an indirect mode of drying, and is based upon the fact, that really dry meat, like soap, (Vol. I. p. 449) is only very imperfectly and with great difficulty moistened by a weak solution of salt, although plain water moistens it readily, the salt consequently prevents it returning to the moist state in which it is capable of undergoing putrefaction. Water has a stronger tendency, therefore, to combine with salt than with meat; dry salt will actually extract a great part of the water from fresh meat, and dissolving in it, form a saline liquid, or brine, without any further addition of water. Under these circumstances a division of the water in the meat is effected; one part is taken up by the salt to form brine, while the other is kept back by the meat, the latter portion being too small to admit of putrefaction taking place. The salt robs the meat of $\frac{1}{3}$ or $\frac{1}{2}$ of the water in its juice, so that only 40 or 50 per cent are retained. It would, however, be a mistake to suppose that water was the only ingredient of the meat extracted by salt, the other soluble ingredients of the juice are removed at the same time, and enter into the brine. The brine thus contains not only potash, phosphoric acid, lactic acid, creatin and creatinine but also a considerable quantity of albumen which coagulates when the brine is heated. It, therefore, contains all the ingredients of a concentrated infusion of flesh, and even more, for the albumen remains for the greater part in the meat when the latter is boiled for soup. The preserving effect of the salt is confined consequently to the fibre of the flesh, and does not apply to the soluble portions. By the process of salting, a separation of several very influential ingredients is occasioned, and the nutritive power seriously injured, so that in fact salting exhausts meat far more than simple boiling. The evil is so much the greater, as the brine is not consumed, but thrown away. When salt meat is almost the sole food, as on ships, the process of nutrition can be but imperfectly carried on; and it is supposed that scurvy, a disease affecting the juices of the body, may be attributable to this cause, which cannot but have a prejudicial effect upon the system. The effects which would be produced by pure salt are fortunately much mitigated by an accidental circumstance; all common salt contains portions of lime and magnesia, (Vol. I. p. 259) which are precipitated by the phosphoric acid of the juice of flesh upon the surface of the meat. The white

crust which may often be observed upon salt meat, consists in fact of phosphoric acid, magnesia, and phosphate of lime.

Sauerkraut.—A similar effect is produced upon vegetables by salt, but is then accompanied by circumstances which give rise to an essential difference. A kind of fermentation often ensues in these cases, which from the chief product it affords, is called the *lactic acid fermentation.* This process was noticed before in a special manner with reference to the souring of milk, and it need here only be further remarked, that lactic acid may be produced from other varieties of sugar, from dextrin, &c. by the action of nitrogenous matters. In the case of milk, cheese is the originating cause, in other cases, diastase and some other substances may produce the same results. The chief applications of these facts, are in the preparation of sauerkraut and salted cucumbers. The brine with which both kinds of vegetables are surrounded, when preserved in salt, is strongly impregnated with two acids, the *lactic* and butyric, as the resulting products of fermentation.

Boiling with sugar.—The principle of preserving by means of sugar, alcohol, and vinegar, depends upon causes which are nearly allied to those which obtain in the use of salt. Sugar, which is chiefly used in preserving fruits, is so applied that a solution of the sugar is effected in the juice of the fruits. The water is thus brought into such a state, that it is incapable of supporting the fermentation or decomposition of the fruits. Very diluted solutions of sugar are, however, exceedingly prone to undergo fermentation, and it follows, therefore, that in preserving, a solution must be obtained which has the consistence of syrup. The drops of water which condense from the state of steam, on the sides of the vessels in which the preserves are placed, are often sufficient to induce incipient decomposition by diluting the upper layers of sugar. The juice of several fruits possesses the property after being boiled with sugar (the presence of which, however, is not absolutely necessary), of gelatinising, this is seen in gooseberries, currants, &c. This property is communicated to them by *vegetable gelatin* (pectin, pectinic acid), which is often contained in the juices of fruits, of turnips, &c. and can be separated from them. In the pure state, it exhibits the properties of an acid, the salts of which likewise gelatinise, and constitute probably the principal part of the jelly of fruits. This substance is very generally diffused in the vegetable kingdom, and belongs from its constitution ($=C_{12}\ H_{16}\ O_{10}$) to the heat-producing ingredients of our food. It is probably

a transition formation between woody fibre and sugar, as may be inferred from its composition.*

Fremy's recent researches "On the ripening of fruits, and the gelatinous principles of vegetables," appear to show that both pectin, and a substance, insoluble in water, which he calls *pectose*, are ready formed in the juices of fruits and roots, and that the weakest acid is capable of transforming this latter into pectin. Pectin is composed, according to this author, in the proportions indicated by the formula C_{64} H_{48} O_{64}, it is converted by boiling water into an isomeric body, *parapectin*, which again with acids yields *metapectin*, or from its feeble acid reaction more properly called metapectinic acid.

Another substance is found associated with pectose in the cellular tissue of plants, to which Fremy has given the name of *pectase*, and it is this body which possesses the property of converting pectin successively into two gelatinous acids. This transformation is effected in the absence of air, and without any evolution of gas, constituting the pectic fermentation which essentially resembles the lactic fermentation. Pectase exists in two modifications in the cellular tissue of vegetables, in a soluble and in an insoluble state. Roots like the carrot and the beet contain soluble pectase, and their juice gives rise to the pectic fermentation, while the juice of apples and other acid fruits, is incapable of acting upon pectin. Pectase is contained in these fruits in the insoluble modification, and accompanies the insoluble portion of the pulp; when this pulp, however, is placed in a solution of pectin, the solution becomes rapidly gelatinous, and then contains two gelatinous acids, the pectosic and pectic acids; vegetable jelly is therefore produced by the transformation of pectin into pectosic and pectic acids by the agency of pectase, or by the combination of pectic acid with the organic salts contained in the fruits.

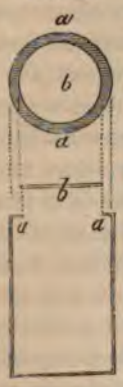
Pectose, which is contained in the unripe fruits, is converted successively during the process of ripening into pectin, metapectin and metapectic acid; these changes being produced by the action of acids and of pectin.

* Vegetable gelatin is often obtained as a neutral, and not an acid product. Mulder considers this neutrality as only apparent, and explains it on the assumption, that the acid in such cases leaves an ash, and is in combination with bases. Others have asserted the existence of a neutral vegetable gelatin, pectin, which without change in its percentage composition, passes under the agency of a strong alkali into an acid, both of which substances, however, occur in nature.

Preserving by means of vinegar.—Alcohol is seldom employed in domestic economy, but vinegar is preferred as a preservative agent. The operation, when this is used, is very simple, but not very certain, as cucumbers, &c. preserved with vinegar often deteriorate. The cause of this is probably due to the very weak vinegar which is often sold, containing seldom more than 5, or at most 17 per cent of real acid. It is consequently easy to conceive that juicy fruits, such as the cucumber, containing often 80 or 90 per cent of water, may so dilute the vinegar as to deprive it of its antiseptic qualities. It is, therefore, advisable to pour off the first portion of vinegar that has been used, and replace it by a fresh quantity.

Preservation by the exclusion of air.—This method, carried out in the manner prescribed by Appert is the most rational, simple and economical plan that could be adopted, and has the incalculable advantage of retaining the food totally unaltered in value, and with its natural taste for a much longer time than any other of the methods already or hereafter to be described. In ancient times it was customary to preserve fruits in oil; thus in Pompeii, in the year 1826, several flasks of well-preserved olives were dug from the ruins, the oil in which they were preserved had however become rancid. It is also an old custom to grease eggs, or to dip them in milk of lime. In either case the pores of the shell become stopped, and the air thus prevented access to the internal parts, precludes the possibility of putrefaction. Eggs may thus be kept for months. Warington has lately proposed a plan founded upon similar principles for preserving the flesh of buffaloes in the American steppes, and rendering it fit to be transported to Europe. He surrounds the meat with a coating of gypsum which is afterwards impregnated with fat. Appert's plan is far preferable and more appropriate, and must indeed be considered of the utmost importance to the health of seamen. The practical improvements to which this method has been subjected in England, require that the vegetables and meats, poultry, &c. be cooked precisely in the same manner as if for immediate consumption. They are then enclosed in boxes of tin plate, of the form shown in Fig. 39, care being taken that no air bubbles remain, and that the viands occupy nearly the entire space of the box; in fact in such a manner as to exclude all air. Thus prepared the lid is soldered carefully to the rim of the box *a* (specially constructed to render the soldering easy), and several

FIG. 39.



of the boxes together are then placed in a vessel of boiling water, and boiled for some hours. If one or other of the boxes is not air-tight, small bubbles will be seen issuing from the faulty spot, which must then be made fast with the soldering iron. During the process of boiling, the oxygen of the enclosed air is entirely converted into carbonic acid, and thus rendered innoxious. This conversion is the result of oxidation, which, however is no longer attended by any decomposition, as that could not take place at the boiling temperature, and any change in the conditions of the viands is thus for ever precluded, as far as air is concerned. Captain J. Ross presented the Société d'Encouragement with a box from the house of Messrs. Gamble and Dorkin, that contained provisions sixteen years old, and which were in a state of perfect preservation.

Ships of the English navy, employed on certain stations where fresh meat is not procurable, such as the coast of Africa, West Indies, East Indies, and China, are now generally supplied with a certain quantity of fresh provisions prepared in this manner by Mr. Goldner.

The contracts for the British navy, for the year 1848 to 1849, amounted to 560,000 lbs. of preserved meats, and 180,000 lbs. of preserved potatoes.

Salmon from the western coasts of Ireland is also sent preserved in this manner to the Liverpool and other markets.

Preservation by antiseptic agents.—There are certain substances in the presence of which, fermentation and putrefaction cannot proceed, or which stop their progress when added to bodies already undergoing that change. The effectiveness of these agents does not appear to depend upon any definite quantities, the most minute portions being often sufficient to stop putrefaction in large masses of matter in a most surprising manner. These remarkable effects cannot at present be explained, and can only be compared to the specific action of certain drugs in cases of disease; most spices are antiseptics, and are very common additions in the methods of preserving already described, for instance, to pickled meat. The most active are the products of the dry distillation of vegetable matter and of wood, as contained in *smoke*. It is well known that meat suspended in smoke is rendered insusceptible of decay, but acquires the peculiar taste of the smoke, a dark colour, and a certain hard consistence, the latter, how-

ever, being attributable to the excessive exsiccation to which it is generally exposed in the operation. Smoking has an advantage over salting, as no nutritive part of the constituents is lost. Amongst the volatile products of tar, which are heavier than water, Reichenbach discovered a substance which dissolves in water to the extent of $1\frac{1}{2}$ per cent, and is far more soluble in acetic acid; this substance possesses a caustic biting taste, and penetrating disagreeable odour, and when pure is in the form of a clear colourless liquid. It is well known under the name of *creosote* (from κρεας, flesh; and σωζω, I preserve). When meat is dipped for a short time in a solution of creosote, it will not putrefy even when exposed to the heat of summer, but gradually dries up, and becomes as if it had been smoked. Meat exposed in a close box, containing an open vessel with creosote, in an atmosphere, therefore, impregnated with the vapour of creosote (upon an ingenious plan proposed by Stenhouse) is found to be precisely in the same condition. In both cases the amount of creosote producing this effect is extremely small. These facts in connexion with another, that creosote is always contained in smoke, leads naturally to the conclusion that the antiseptic property of smoke, tar, and wood-vinegar must be explained by the creosote they contain. Creosote possesses the peculiar property of coagulating with extreme energy, and rendering insoluble, the albuminous portions of blood; the aqueous solution of creosote does this somewhat more tardily; these facts point to the source whence the explanation of the phenomena of preservation must be looked for, for animal matters decompose with the greatest difficulty when in an insoluble state.

II.—TECHNOLOGICAL PROCESSES CONNECTED WITH AGRICULTURAL INDUSTRY.

A. EDUCTS.

MILLS IN GENERAL.

Historical.—The development of industry leads necessarily to a constantly increasing division of labour. The simple habits of the ancients included amongst the ordinary occupations of domestic life, the operations of spinning, bleaching, weaving, dyeing, and dress-making; while in modern times these are each and all

carried out in separate manufactories. The ancients likewise knew nothing of millers and bakers. It was left, as Pliny relates of the ancient Romans, to the house-wives, or to slaves to bake from the threshed corn what corresponds to our present bread, and which was no doubt unleavened. Although the corn was often consumed in a simply roasted state, yet it is stated in the first book of Moses how Abraham placed cakes before his guests prepared from the finest meal; and afterwards in the fourth book, that manna was sometimes ground like meal. So it was amongst the Greeks and Romans, where the grain was crushed or stamped to meal in mortars (pilæ), with pestles (pistillæ). For this reason the bakers in Rome were called stampers (pistores). After a time the grinding surfaces of the (stone) mortars were roughened or sharpened as a miller would now call it, and the grinding was effected more by a rubbing than a stamping motion. When at length the handles of heavier mortars were worked by levers and slaves, the mortar became converted into a mill, and the use of animal in place of slave labour and the substitution of the *runners* and *bed-stone* for the pestle and mortar, was then an easy step in advance. The bedstone was called in Latin, *catullus;* the name of the runner, (*meta*, a conical pillar), for a long time unintelligible, was explained at the excavation of Pompeii. In the court of a bake-house, two mills were found perfect, and in their original position opposite the oven; although of larger dimensions, these mills were constructed upon precisely the same principles as our present coffee-mills, *i. e.* the grinding was effected between two conical, roughly hewn surfaces, of which the convex cone was fixed as the bedstone, while the concave surface as the runner was inverted over it. In order to move it easily two holes opposite to each other were made in the direction of its diameter for the insertion of levers. Through the open top of this meta, the grain was poured in between the stones.

Up to this period grinding and baking were departments of one and the same trade, and they remained connected for a very long time. The operatives (*pistores*) did not exist in Rome, according to Pliny, prior to the year 172 B. C., and they came originally from Greece. When natural powers were made to supply the place of manual labour, and mills on a large scale were erected, then the miller's trade was first separated from the baker's.

Water-mills appear to have been known in Asia in the time of

Cæsar or Cicero, or even in that of Mithridates, and were introduced at Rome shortly before the reign of Augustus, when they were described by Vitruvius, and celebrated in verse by Antipater. They only superseded hand-mills when Christianity had abolished slavery. The first accounts of floating mills is afforded by the description of their being constructed by Belisarius, when besieged by the Goths in Rome (536). Windmills are first mentioned about the year 1105. The use of sieves in grinding, as well as the so-called *nets*, was known to Pliny; the use of flat millstones is also of ancient date; but in their subsequent form, mills are first encountered after the discovery of the bolter-cloth and bolters (sieves for separating bran from flour).

Mills stood for a long time prominently at the head of the mechanical contrivances of the day under the auspices and empiricism of well-trained and experienced mill-doctors. In more modern times the reverse has been the case, and the construction of mills has remained far behind the mechanical science of the age, partly in consequence of legal restrictions and monopolies interfering with active improvements, and partly because mechanical science appears to have passed over the construction of mills as beneath its notice. Since however, in the beginning of this century, the attention of engineers has been turned to the improvement of mills, their construction has attained the full advantage of modern invention, and the improved mechanism of *power-mills*, particularly the *American mills*, promises speedily to put an end to the old empirical system. This competition between modern intelligence and monopoly is now coming into full activity. In order to understand the principles of the old and new systems, and the advantages of the latter to the public weal, it will be necessary to take a glance at the structure of the grain and the relation of its structural parts.

Each separate grain of corn contains a floury kernel, enclosed in a dry, firm integument, or seed-covering (*epispermium*). This straw-, or leather-like coat, is not digestible, and can consequently not be reckoned among the nutritive constituents of the grain; it constitutes in wheat 14, in rye about 11 (according to Hermbstädt), and in barley 5 per cent of the entire seed.*

* Hermbstädt estimated the husk in barley at 13 per cent. It is not only very difficult to ascertain the exact amount of the husk, but the quantity is also variable, according to season.

The floury contents of the kernel are also not perfectly digestible, when raw flour is consumed, a portion of the starch passing away undigested. In other words, the granular structure of the starch must be broken up by heat, either by boiling or baking, in order to be thoroughly assimilated. Grain is therefore first converted into actual food when the husk or bran is separated from the flour, and this is the object of grinding, the flour being then rendered digestible by boiling or baking.

The produce of the mill entirely depends upon the structure of the grain. As far as our knowledge extends, it appears that the gluten is collected more at the surface, or immediately under the husk of the grain, while starch preponderates in the centre. The flour from the surface is more nourishing, that from the interior is whiter. The husk of corn is so firmly attached to the central portion that the one can never be thoroughly separated from the other, and this separation is much impeded by the small size of the grains. It follows consequently from this, that every grinding process inevitably falls into one or other of the following errors: it either grinds the husk too much, which then mixes with the flour, or too much of the flour remains attached to the husk. This latter evil is of greater consequence, as the most nutritious part of the flour is that which remains attached to the husk. It is further obvious, that in the course of grinding the outer portion of the grain must be first subjected to the action of the mill, and the first ground portions may differ considerably in chemical constitution and in nutritive power from those which follow. Whatever arrangement may be adopted in the mill, the finely-ground portions of flour are collected separately by means of the bolters, one after the other, and consequently the kinds of flour in commerce, from one and the same grain, will possess a more or less similar character (independently of the amount of bran they contain), according to the manner in which the different products are mixed previously to sale.

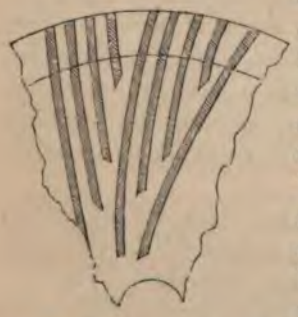
Old German mills.—The older German mills are always furnished with several pieces of machinery placed side by side, each of which is in itself a complete grinding apparatus. They are called "*Gänge*," each "*Gang*" comprises three pieces of apparatus working in unison:

1. The actual grinding apparatus, which produces the flour;

2. The hopper, which supplies the grain in proportion as it is ground;
3. The bolter case, in which the ground grain is separated by sieves into the different products of the mill.

The mill-stones.—The principal part of the grinding apparatus consists of the two flat, cylindrical mill-stones, the axes of which are placed exactly in one perpendicular line. The lower, or *bed-stone,* is permanently fixed; the upper stone, or *runner,* is moveable upon its axis, in such a manner that the two surfaces opposed to each other are always precisely parallel, and the distance between which can be regulated at will. When the grains are introduced between the stones, the inequalities in the bed-stone tend to keep them from advancing, while those of the runner propel them forcibly forward. The grain is thus torn to pieces. In order that the fragments, however, shall be ground finer, the runner ought to sink down as the particles are reduced in size. If it were allowed to sink by its own weight, an excessive degree of friction would ensue, destroying the stones and accompanied by much heat. To avoid this, the so-called "dressing" has been applied, which allows the grain to be ground perfectly fine, while the entire weight of the runner is borne by its axis, and not by the bed-stone and the grain. The distance between the stones must be capable of regulation, in order to ensure any degree of fineness, and that the substance to be ground may be brought wholly within the compass of the grinding surfaces. By dressing is meant a peculiar grooving of the grinding surfaces according to a certain plan, the grooves in the upper stone being adapted in such a manner to those in the bed-stone, that when the stones are in motion, an action similar to that of shears is exerted. This will be understood by reference to Figs. 40 and 41, (which show the grooving of two stones in profile),* where the space left by the hewn furrows becomes more and more narrow, so that grains enclosed between the stones are gradually crushed, until they at length come

FIG. 40.



* These grooves are never actually so sharp and clean as the drawing represents them.

FIG. 41.

to lie between the plain surfaces, and are there reduced to powder. This is the American plan of grooving the stones, (according to Evans), and is considered the best; formerly, and even frequently now, similar, but straight furrows are cut, as is seen in the drawings of the mill-stones of a French power-mill, Figs. 42 and 43. Here the profiles of the furrows are of a different form, but they act in a precisely similar manner. In the ordinary mills, as represented below,

FIG. 42.

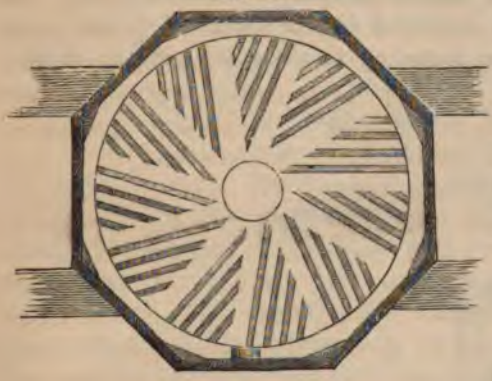


FIG. 43.

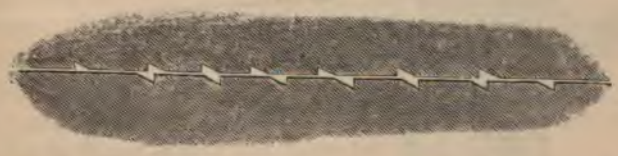


Fig. 46, the common mode of grooving is different for each stone, as represented in 44 and 45. Spiral grooves proceed from the centre of the runner to the circumference, while the radii in the bed-stone are straight.* Each time the grooving is renewed, every second or third day, the miller transposes them

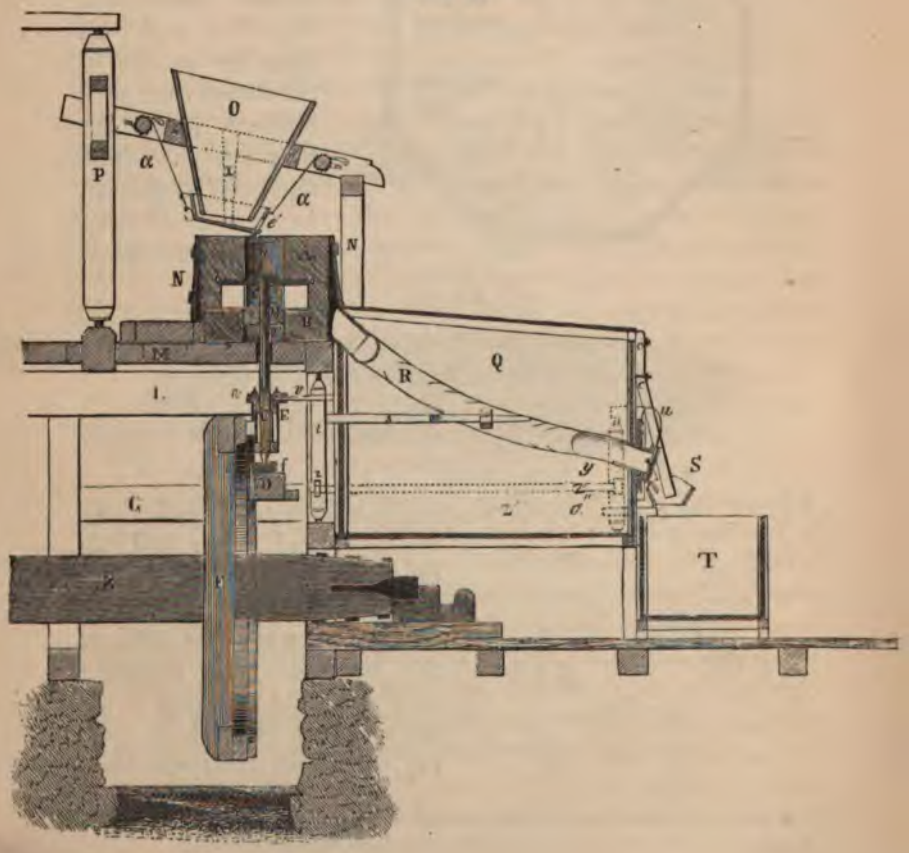
FIG. 44.

FIG. 45.

* The wide furrow *x y*, passing through the runner in the direction of the diameter, is cut for the purpose of admitting air freely between the stones.

so that the spiral grooves are cut into the bed-stone, and the straight grooves in the runner (Fig. 44). The material of which the stones are composed is of great importance; it should be hard enough to withstand much wear, and yet not so hard as to render the grooving difficult. All stones that become smooth or very blunt by use are unsuitable, as it is an essential condition that they should remain rough. For this reason, the stones hewn from Rhenish lavas are preferable, as they, from their blistered structure, wear down with sharp edges. When there is a scarcity of material, mill-stones may be constructed of several pieces. The size of the stones is regulated by the extent of motive power at command, or varies according to the custom of the country,

FIG. 46.



from 3 to 7 feet in diameter. In Fig. 46, which shows the different parts of a mill in working order, *A* is the runner, and *B* the bed-stone. In order that the grain may be introduced between the stones, an opening of 6 or 8 inches wide, *a*, (*the eye*, Fig. 45), is cut through the runner. As soon as the grain thus introduced has once acquired the motion of the stones, it is incessantly driven by centrifugal force towards the periphery, reaching which, it leaves the stones in the state of flour, and would be thrown about in all directions if the latter were not surrounded by a kind of inverted tub, *N*. The motion of the runner *A* is communicated from below, through the bed-stone, in the following manner:

An iron bar *b* is fixed into the runner across the aperture or eye *a*, (a vertical section of which is given in Fig. 47); this is called the ryne, into the handle of which the quadrangular end of an iron axis *C* is firmly fixed. The runner is therefore supported by means of the (mattock?) upon this axis *C*, called the spindle, the opposite end of which rests in the conical steel bed *f* of the beam *D*. This bed bears, consequently, the entire weight of the runner. The beams *G* (upon which *D* is supported) and *L* together form a kind of leverage, by means of which any position in an upward and downward direction can be given to the cup *f*, and, consequently, to the spindle and runner. The spindle passes through an aperture *g* in the bed-stone (Fig. 44), similar to that of the runner; this is called the box, and being lined with wood, fits sufficiently tightly round the spindle to prevent shaking. Between the socket *h*, and the foot-step *f*, the pinion *E* is attached to the spindle, into which the teeth of the cog-wheel *F* work, which is driven by the water-wheel, and cause the rotation.

FIG. 47.

A constant and regular addition of the grain to be ground must be supplied to the stones, that they may not be left without grain between them, or choked by too abundant a supply. This is effected by the hopper, consisting of a large funnel-shaped box of wood *O*, which contains a sufficient quantity of grain to feed the stones for some time. The motive-power of the mill itself regulates the supply of this grain through the aperture *e'* into the eye *a*, so that the stones are at all times supplied with as much corn as they can grind, and in the following manner: The bottom of the hopper is constructed of a flat, wooden, moveable box *e'*, called *the shoe?* which from the mode of its suspension by the cords *α α*,

and round the fluted rollers *m*, adjusts itself so as to close more or less the mouth of the hopper, and thus regulate the feed. A

FIG. 48.

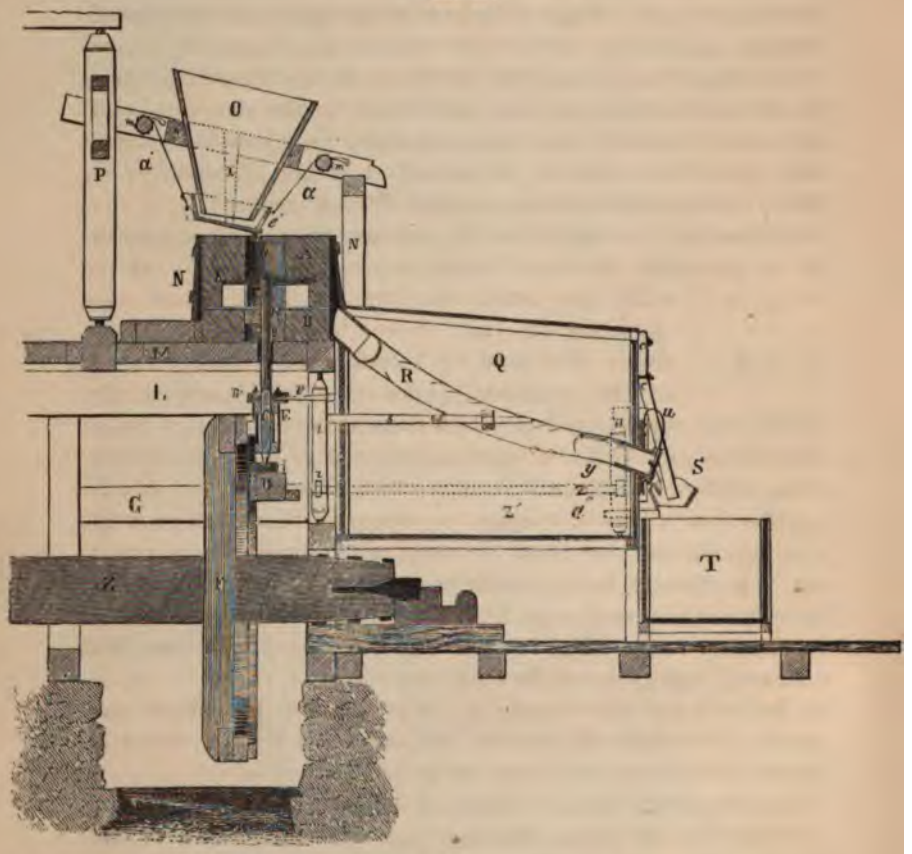
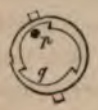


FIG. 49.

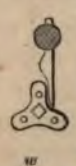


shaking motion is communicated to the hopper in order to maintain a continuous feed by an iron pin *p*, more distinctly shown in Fig. 49, attached to the shoe in such a manner as to project some inches into the aperture of the runner, in the upper edge of which an iron ring with notches is inserted which alternately force the pin *p*, and, consequently, the shoe in a direction towards the centre of the aperture, and then

allow it suddenly to fall back again. A spring *x* tends to increase this motion. To prevent the grain remaining in the aperture *a* and stopping up the passage, a rod (not shown in the drawing), attached to the surrounding drum, projects into the aperture and keeps the grain contained in it in constant motion.

In the casing *N*, in the direction of the flour-chest *Q*, a quadrangular hole is situated, which conveys the ground meal to the sifting or bolter apparatus, in which the flour is separated from the bran. This is effected by the bag *R*, extended in front of the aperture of the casing. This bag consists of a kind of tubular sieve, constructed of a particular fibrous material, called bolter cloth, through which the coarser particles pass out to the bran-box *T*. The fine particles of flour fall through the pores of the cloth from the incessant shaking motion communicated to the bag, which is effected by a fork-shaped rod *s*, fixed at one extremity to the bag, and at the other to the perpendicular revolving cylinder *t*; from *t* a similar rod or appendage *v* passes backwards to the pinion *E*, which comes in contact with the triangular piece *w* attached to the spindle. The manner in which this moves the piece *v* will be obvious from the drawing, Fig. 50, as also the way in which this alternate motion is communicated by means of the spindle *t* to the rod *s*, and thence to the bag *R*. The bag is terminated by leather *y* at both ends, and thus fixed to the sides of the flour-box.

FIG. 50.



The portion which does not pass through the bolter-sieves, as meal into the meal box, is bran and coarse flour, and is conveyed directly either to the bran-box *T*, or first to the sieves *S*, where the coarse flour is separated from the bran. The rocking motion of the sieve *S* is obtained by means of the wooden spring *c* and the spindle *z* through the conducting-rod *d'*, in precisely the same manner as that of the bolter sack, only in this case the rod *d'* and the arm *a''* form a right angle to the spindle *z'*.

The quantity of grain which is ground at one time, or the charge, must be passed several times, as often as six or even twelve times, one after the other, between the stones; the relative position of the stones being changed each time, and accommodated to the degree of fineness required. It must also be here remarked. that the distance between the stones is greatly increased by wear, and the surfaces would, at length, no longer touch the grain.

To remedy this, the millers are in the habit of lowering, from time to time, the cross-piece *b*. The grain, after passing two or three times between the stones is reduced to coarse fragments, called ——? The ——? when deprived of as much flour as is practicable in this operation, by being repeatedly returned between the stones, is called *bran*. That portion which passes as dust through the bolter-cloths affords the different qualities of flour, while the residue in the cloths deprived of the husk is called ——? The flour, or meal, is itself very variable in quality, according to the number of times it is passed between the stones and bolter-sieves, and according as the portions passing through these are subsequently mixed with each other, or retained separately; all which is regulated by the peculiar demands of the locality in which the mill is situated, but would be out of place to describe here more minutely.

Comparison between the steam-mills and those of older construction, with reference to the cleaning process.—It is of great importance to examine upon what the value of the products of the mill depend. And here the preparation of the grain, as far as relates to the *cleaning* and *moistening*, will be found most influential. All grain—particularly when not carefully harvested, or collected in bad, rainy seasons, is more or less mixed with earth, sand, and even stones, and the operation of threshing rather adds to than diminishes these; dust likewise collects on the rough husk. In addition to this, the grain may contain foreign seeds (weeds), which either give a bad taste to the flour, or are innutritious, and even injurious, and there are frequently microscopic fungi (smut, &c.) disseminated through it, which are extremely prejudicial to the quality of the flour. The separation of any of these impurities from the corn is very imperfectly effected by the old German process, it is sometimes totally neglected, and was not at any time specially attended to. It constitutes, on the contrary, in modern mills, constructed with all the latest mechanical contrivance, and which are of either French, English, or American origin, an essential and extensive part of the entire machinery.

The practice of moistening took its origin from the practical observation that the husk of grain could only be properly removed when it possessed a certain degree of toughness. This is not the state of the grain as it comes into the market, it is too dry, and requires moistening. The miller, therefore, immerses a certain portion of the grain in water, and removing the light seeds which

float on the surface, adds, after drawing off the water, the dry portion of the grain to it, both being then allowed to remain for some time in contact. Others sprinkle water over the grain. Although the moistening is to a certain extent a cleansing process, it has the disadvantage of producing flour in a more moist state than natural, and consequently less adapted for keeping. The more modern, better-constructed mills obviate entirely the necessity for moistening the grain, and lessen the evil of too high a temperature and an admixture of husk with the flour, which dry corn would contract between the stones, by a more appropriate grooving in the stones. This greatly facilitates the skinning process, and special mechanical contrivances are applied for cooling the ground meal before it is sifted.

Thus far the quality of the meal is improved, and the amount of produce speaks equally in favour of modern mills. The more thoroughly the husk is separated from the actual grain prior to being ground, without at the same time being converted into dust and small fragments, the more completely can the two be separated from each other, *i. e.* the amount of flour will be increased, and its quality better, according as it contains a less quantity of husk, and at the same time the smallest quantity of coarse flour will be carried away with the bran. Steam mills are constructed specially with a view to this. In the older mills, from the want of a proper covering to the different parts of the machinery, dust flies about incessantly, which is not only a source of loss, but being deposited in all the crevices, occasions irregularities in the working of the different parts. Care is taken in modern mills to prevent this as much as possible. The process of grinding is carried on continuously, fresh grain being constantly introduced, and not in certain portions at a time which have to be passed several times between the stones; the grain thus leaves the mill thoroughly ground at once, and the sieves separate it more perfectly into a greater number of products which are more suitable for the market.

The other advantages consist in improved mechanical arrangements, which save power and lessen the number of hands required. The most important points tending to this general object are here shortly noticed.

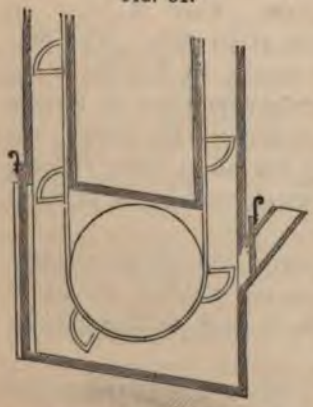
In the old mills, the cross-piece and the spindle are connected immoveably with each other, so that the runner is much impeded, and prevented from acquiring a parallel motion to the

bed-stone, which causes irregularity in the working. The runner in the new mills is balanced in a semi-circular socket of its cross-piece, which for this reason is placed above its centre of gravity, upon the rounded end of the spindle instead of being firmly attached to it. This arrangement admits of an easy, unconstrained motion, tending in itself towards a parallel direction.

There are generally three kinds of cleaning apparatus. The first consists of a series of sieves, which separate the coarser foreign particles (stones, straw, &c.) from the grains of corn and finer impurities. These are sometimes in the form of flat rimmed sieves, sometimes cylindrical, two or more together. The second is a sort of mill-work, the stones of which are so far separated from each other that the sharp points of the grains alone are ground off, which in themselves contain no flour. The third is intended to free the surface of the grains, by attrition, from dust, and dirt, &c., and this is effected by a cylinder lined with brushes, which scrubs the grains against the cylindrical file-like surface of the box in which it moves. The dirt is then blown away from the cleaned grains by means of a current of air produced by a fan.

The meal after leaving the stones is always hot, in consequence of the friction to which it has been exposed. Warm meal, heaped up, is sure to spoil (to be chemically decomposed). It is consequently absolutely necessary to cool it, and this is done in machines which spread out the ground flour into thin layers, and constantly stir it about with a species of rakes.

FIG. 51.



The removal of the grain and other products of the mill from one floor and one machine to the other, is done by an Archimedian screw, or endless chain of buckets, Fig. 51, moving in an upright shaft, and carrying the dry material to any part of the building.

The husk of the grain in the thoroughly dry state is so hard and brittle that it is partly ground to powder, which is sufficiently fine to pass through the bolter sieves. Moistened to a certain extent, it acquires a leathery consistence, which, preventing its being ground to dust, leaves it in larger shreds. In the ordinary state as dried

in the air, the husk is still somewhat too brittle, and passes too easily as powder through the sieves. This is one reason why millers often moisten the grain; but as very dry grain is much more difficultly ground than moist, and consequently requires better millstones, which are not always to be procured, this is another reason for moistening.

In proportion as the moisture is favourable to the operations of the miller, so is it pernicious to the quality and durability of the meal, particularly if the latter has to be carried to a distance. In the experiments of Mitscherlich and Krocker, noticed above, the absence of sugar was proved in a specimen of wheat, the flour from which afterwards yielded 4 per cent. This formation of sugar affords a strong proof that a very slight degree of moisture has a tendency to produce decomposition in meal which would nevertheless be generally considered of very good quality. That this influence is sufficient to extend the decomposition to the entire destruction of the meal, is a fact of every-day occurrence, and exhibited by the meal becoming *mouldy* and *acid*. In what these changes consist, which are evinced so clearly to the taste and smell, with reference to the gluten, the starch, &c., is well worthy of investigation; thus much is known, that a mass of flour becomes acid chiefly in the centre and to a far less extent towards the outside where the air has greater access. In this state the meal has a tendency to ball together in lumps, becomes rough to the feel, like coarsely ground gypsum, and is much less fit for bread. It is well known that this change is unavoidable in meal that has been moistened, and which contains a larger amount of moisture than when in the natural state, and that a damp place favours the change.

An experiment made in the mill at Berg proves, however, that the same change takes place in natural unmoistened flour, although not so speedily. Spelt of the growth of 1832 and 1833 was ground, and the second and third quality flour was packed in April, 1834, into eighteen casks, each containing 400 lbs., and kept in a cool, airy and dry warehouse. The casks opened in September, and even on the 1st of November, were unaltered, with the exception of evolving a more powerful smell of meal; others, opened in the middle of November, or from six to seven months after packing, exhibited a strongly acid smell. In the beginning of February, after nine months, therefore, all the flour of the third class (which contained the largest quantity of gluten) was completely acid and spoiled.

The facility with which flour is spoiled, and particularly at sea, is the very important reason why the trade in corn is not universally superseded by the trade in flour, which would be a more convenient and, as far as carriage is concerned, cheaper mode of equalizing the rich crops of one with the poor or failing crops of another country. By drying the grain, as in England, at a low temperature in a kiln, the flour is rendered more fit for keeping, but in other respects the practice has disadvantages, which are obvious when English- is compared with American-flour that has been ground from undried grain. English flour is not so white, often spotted (partly from the dust of husks or from the grains being imperfectly cleaned), but it is drier and keeps better; American flour is the whitest of all; prepared in better sifting machines, it has a soft, not gritty feel, like the former; it is cooled in special apparatus, while the former is allowed to cool only in sacks. In England a larger quantity of flour is obtained on the whole, and a bran which whitens black cloth very slightly with flour; in America less is obtained on the whole, but 4 per cent more of the finest flour, while the bran is left very mealy.

The only method of securing flour of the quality of the American, and the durability of the English would be to grind unmoistened, or when the stones are soft, slightly moistened grain, but in any case undried grain, and to dry it, before packing, at a low temperature, as has been practised in some places for sea-transport with the best results.

The flour from steam-mills is much more durable than that from those of older construction, but the great obstacles to the general introduction of the former are not alone dependent upon the larger amount of capital required in the first instance, and the necessity for some artificial source of power, but chiefly in the circumstance that small portions of grain cannot be ground for individuals in the customary manner, and the public must consequently first adapt itself to an alteration in the division of labour and mode of carrying on business.

As an instance of the difference in the amount of production of the old and new mills, there was obtained as a mean quantity after six repetitions of the grinding process in an old mill:

Fine flour . . .	55 lbs.	Fine flour . . .	40 lbs.
Middle flour . . .	18 „	Coarse flour . . .	20 „
Black flour . . .	9 „	Middle flour . . .	10 „
Bran	18 „	Black flour . . .	5 „
		Bran and loss . .	25 „
Maize . .	100 lbs.	Barley . .	100 lbs.

In a new mill at St. Maur, near Paris, there were obtained:

Flour of the first quality . . .	72 lbs.
„ „ second „ . . .	3 „
„ „ third „ . . .	3 „
Coarse bran	7 „
Fine bran	10 „
Black bran meal	3 „
Separated by sieves	1 „
Loss	1 „
Wheat .	100 lbs.

When it is borne in mind that a runner becomes blunt in twenty-four hours, and in that time about 2 lbs. of dust are rubbed off the stones, it is obvious that the dust from the stones must be mixed with the meal in very considerable quantities. This is chiefly the case in the beginning of the operation, but the meal thus adulterated is deposited chiefly between the jacket and the stone, in the space below and behind the flour-hole, and does not mix with the other portions of the flour, these being only incorporated with the finer dust that is afterwards rubbed off. According to the Bavarian Industrial Journal, the following quantities of stone-dust were found in the cwt. (112 lbs.) of the following kinds of flour from three different mills:

	Best meal.	Second flour.	Wheaten flour.	Baking flour.
1	0.82 oz.	0.32 oz.	0.28 oz.	0.16 oz.
2	0.19 „	0.64 „	0.38 „	0.20 „
3	0.38 „	0.48 „	0.32 „	0.54 „

We insert here some drawings representing a more modern mill of the most approved and finished construction, planned by Mr. Fairbairn.

Fig. 52 represents a sectional elevation.

Fig. 53 a sectional plan corresponding to Fig. 52.

Fig. 54 a transverse section of the whole mill.

The literal references below will render the different parts and their functions intelligible, more than which it would be beyond the province of this work to enter into detail.

A A A. Sheet-iron sides of the house in which the mill is erected.

B B B. Columns for supporting the same.

C C. Horizontal beams passing round the house at the level of the first floor.

D D. Corrugated iron roof.

E E. Masonry for foundation for bearings of driving gear.

F. Steam engine.

G G. Boilers with *H H* Flues.

I I I. Transverse cast-iron beams with

J J. Columns for supporting the same.

K K. Spur fly-wheel of engine.

L. Pinion working into the same.

M M. Main horizontal shaft of the mill.

N N N. Bevel mortise wheels and pinions for driving mill-stones.

O O O. Framework of grinding machinery.

P P P. Mill-stone cases.

Q Q. Large garner for uncleaned wheat.

R. Spout leading from same to

S. the screening machine.

S'. The dressing machine.

T. Fan attached to wheat screen.

U. Spout leading from this screen to

V W. the first elevator.

X. Passage conducting grain from ditto, to

Y Y Y. the creeper, by which it is distributed into

Z Z Z. the garners for feeding the stoves.

A A A. Feeding pipes made of tin plate.

B B B. Pipes by which the flour is withdrawn from stone cases into

Y' Y' Y'. second creeper-box, conducting to

V' W'. the second elevator.

And the remaining letters refer merely to some mechanical details.

FIG. 52.

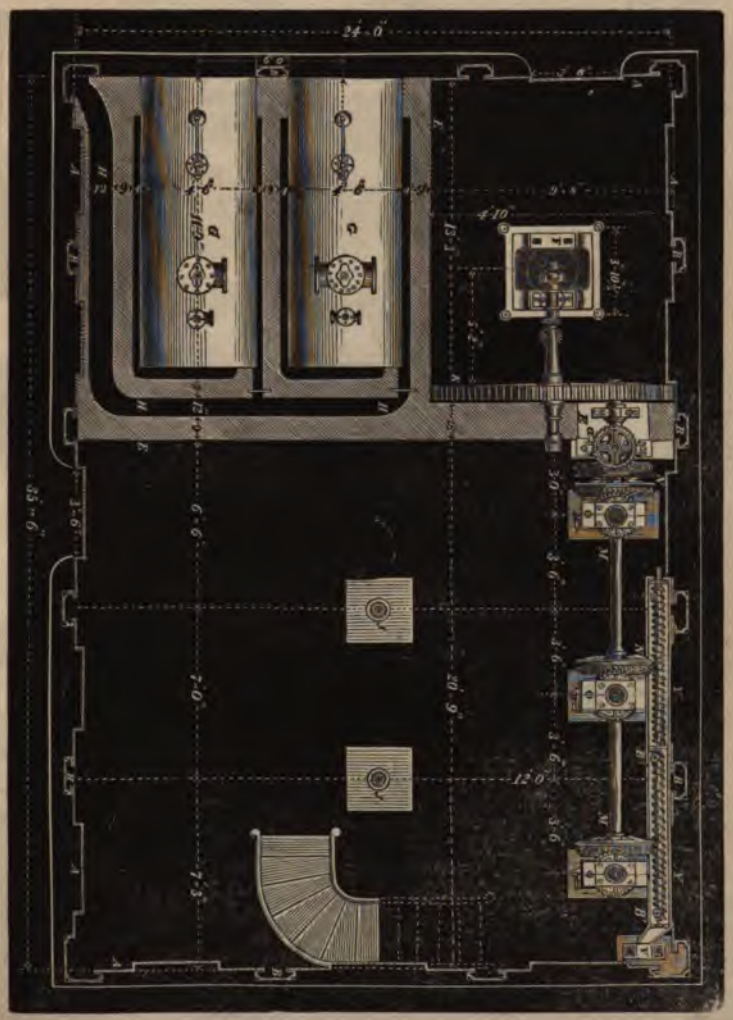


FIG. 53.

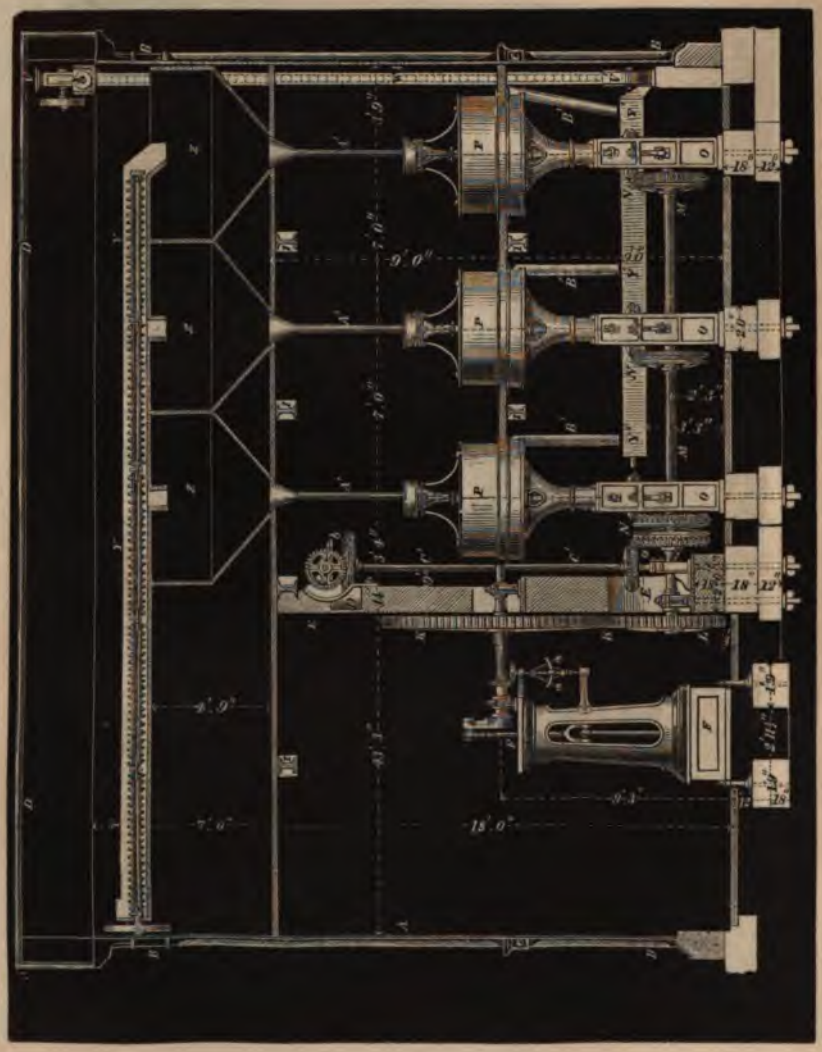
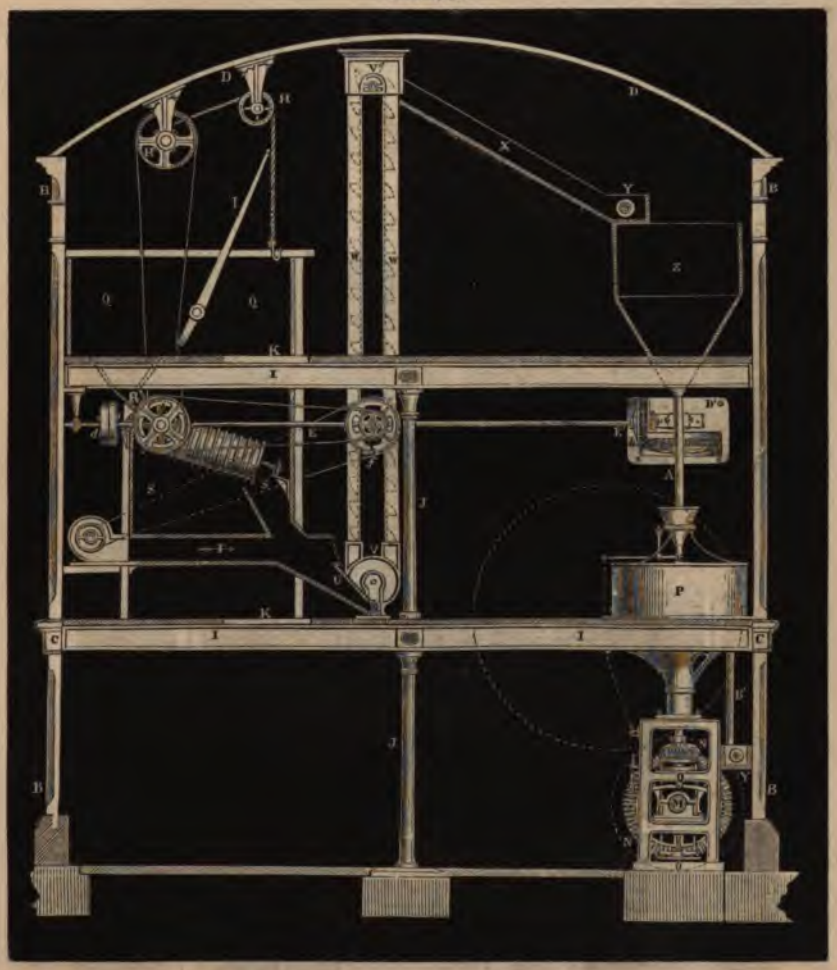


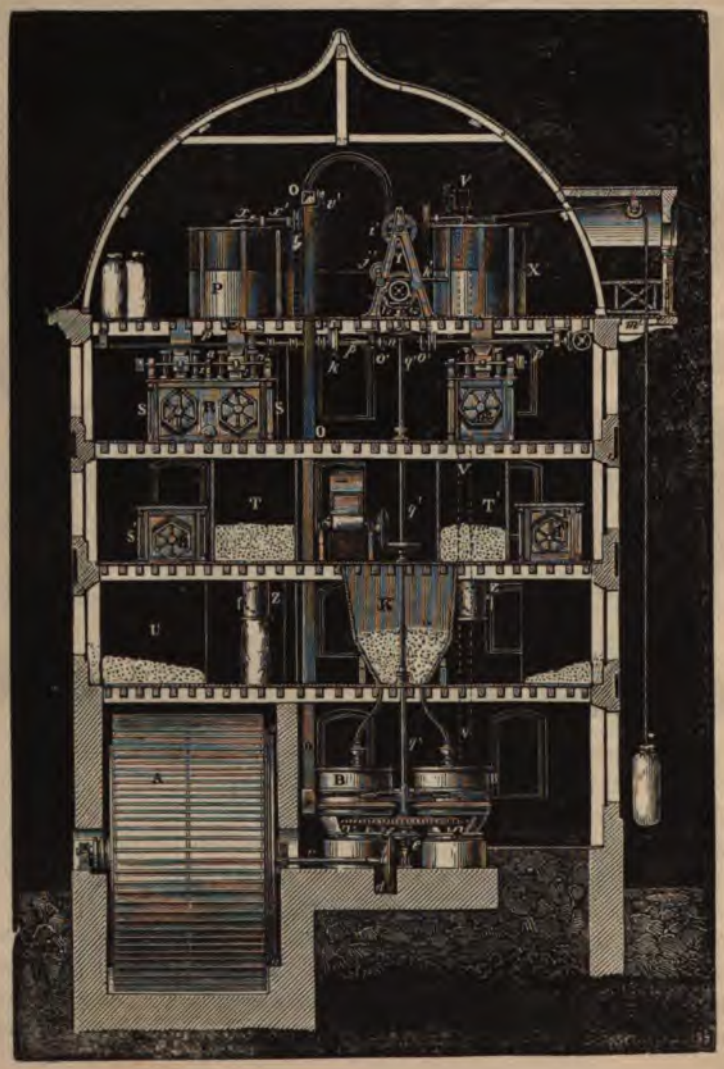
FIG. 54.



The sketch, Fig. 55, is a sectional view of the interior arrangements of a flour-mill, for grinding corn, as adopted in France. The machinery is put in motion by means of a large water-wheel *A*, which is communicated to the stones *B B* in the ordinary manner, by a spur-wheel *a*, and pinion *b*. An upright shaft *q q q* conveys the necessary motion to the other parts of the machinery. The corn is cleansed by the winnowing machine *L* before it descends into the hopper *K*, whence the stones are supplied. The flour, as it comes from the stones is raised to the top of the building by an endless chain of buckets *o o o*, and delivered into

a machine *P*, where it is agitated by means of rakes. It then descends into the dressing or bolting mills *R R R*, and the various qualities are finally collected in sacks, as shewn in the sketch. The mode in which the corn is raised and brought into the mill is also shown at the right hand side of the drawing. The other mechanical details may be found described at length in a work by Armengaud, Vol. VI. p. 315.

FIG. 55.



OF BREAD.

The digestibility of any kind of food depends not only upon its chemical nature, but quite as much upon its proper mechanical structure, when alone it can be properly divided by the masticating organs, and well mixed with the saliva. The form given to the meal of the greater number of the cereal grains so as to combine these two requisites is that of bread, which likewise adapts them for easy portability, a circumstance of no small importance to the poorer classes, while it renders them capable of being kept for some weeks.

When meal is worked up with water and dried, a cake is obtained which binds together without any great degree of firmness, but in which the starch is still in an entire state, and not dissolved; the cake is insipid and indigestible. If the cake is dried with artificial heat which thoroughly permeates the whole mass and attains 100° (212° F.), the starch is then converted into a soluble state, but the cake is firm, dense and compact, and very difficult of digestion. If the heat is such that the surface only, and not the internal portion of the dough attains the temperature requisite for completely disintegrating the starch, a cake is produced which is either doughy internally, or when too much water was not used in the making and the heat is continued to dry it up, possesses a character intermediate between the hard glassy and the mealy. This latter kind of bread was universal in former times, and is still eaten in Scotland, the north of India and Afghanistan. It is prepared by the Jews as pascal bread, and ship-biscuit is composed of it. The preparation of this kind of bread is mainly dependent upon the drying of the dough, it is therefore always in thin cakes, and never in large loaves. This bread is characterised by the small amount of moisture it contains, and by its great density, which quality interferes considerably with mastication. Its dryness gives it an advantage over ordinary bread, rendering it capable of preservation for a much longer period, but it is deficient in lightness, although this does not interfere with its digestibility, nor with that agreeable taste which arises from the roasting (incipient decomposition by heat) of the surface of the dough, and which is inseparable from the idea of good bread. Indeed, the English biscuit, however nutritious, is very insipid.

Object of baking.—The art of baking bread consists in producing a crust, or roasted portion, and a crumb, which while it is

sufficiently acted upon by the heat to render the starch soluble, is not shrunk into a dense, glassy or doughy mass, but remains porous and spongy. In this state it can be easily masticated, and a large surface is exposed to the action of the digestive juices. Various means are resorted to for ensuring this porosity; thus in the Spanish dough, or pie-crust, it is produced by the fat, which separates the numerous extremely thin laminæ. The vapours evolved by the heat of the oven separate the different layers, and collecting between the strata of fat, thus raise the dough. A simple and less expensive means is employed in ordinary bread by *fermentation*.

Ferments.—The ordinary bread of Germany is generally raised by means of *leaven*. For wheaten flour, which yields white bread, and is almost exclusively used in some countries, as in England and France, &c., *yeast* is employed as the ferment in place of leaven. This is not the case with *black bread*, which is the principal farinaceous food of the people of Germany, Russia and the north of Europe. Three materials are indispensably necessary to bread, independently of the milk, butter, &c., which are added to pastry, and are of subordinate importance; viz., *meal*, *yeast* or *leaven*, and *water*. To these *salt* may be added as equally essential, and sometimes condiments, as caraways.

Fermentation raises the dough by an evolution of gas through its entire mass. When the process is properly conducted, all parts are simultaneously affected, and the fermentation spreads through every part, which swells from the bubbles of gas. In mixing the flour with water, the object is to avoid any excess of the latter, and only to use a sufficient quantity to communicate the greatest degree of extensibility to the particles of gluten. Too much water would prevent the adhesion of the glutinous particles and separate the ingredients of the flour, while the proper quantity renders it stiff and extensible as far as is required by the ferment to raise it. The tough consistence of the dough, when intermediate between a solid and liquid state, prevents the small bubbles of gas from uniting into larger ones or from rising to the surface; they consequently expand in the exact spot where they are generated, and thus *raise* the dough.

Character of the fermentative process in bread.—It has been clearly proved by experiment that the gas concerned in raising the dough is carbonic acid, which is accompanied by alcohol, and there can consequently be no doubt of the vinous nature of the

fermentative process which has its origin in the sugar. In treating of the chemical characteristics of the varieties of grain, it was observed that a certain amount of sugar is soon generated in flour to the extent of 3 or 4 per cent, although this did not exist in the original grain. Bread-fermentation is, therefore, a decomposition of sugar into carbonic acid and alcohol by means of a ferment, with the view of rendering the bread porous; it is a sacrifice of this one constituent in order to produce this change of texture. Its object is purely mechanical. The observation is not without interest, that the raising of the dough may be completely prevented by the addition of a very small quantity of soap-suds. This practice, sometimes used as a trick upon bakers, is explained by the absorption of the carbonic acid by the soap-suds, which at the same time softens the dough and deprives it of tenacity.

It is not probable that the process of fermentation is solely confined to the transformation of the small quantity of sugar which may happen to be present in the dough; but, on the contrary, it is almost certain that the chemical action extends further, and induces the gluten to act upon the starch in a similar manner as is observed in the process of malting, converting a portion of it into sugar. The evolution of hydrogen, which is said by some to accompany the carbonic acid, would favour this supposition.

The means employed for inducing fermentation is of the greatest importance with reference to the quality of the bread. It is well known that dough is capable of undergoing spontaneous fermentation; but Fownes has shown that ordinary dough prepared with wheaten flour at the usual temperature of the room, only arrives at the condition necessary for producing fermentation in brewers' wort after the expiration of six or seven days, and acquires a bad odour and acid properties before that period has elapsed. It is therefore practically of importance that dough should at once be submitted to the vinous fermentation. If yeast is used for this purpose, of which a very small quantity suffices, no trace of it can be detected, or of the bitter taste it possesses, in the bread, and the mechanical effect is produced without any difficulty. This is not the case with black bread, for which *leaven* is employed. Leaven consists of a portion of the dough already undergoing fermentation, which is preserved from a former baking to be mixed with the fresh dough. It gives rise to fermentation upon the same principles as is the case when fermenting wort is mixed

with fresh wort, or fermenting grape juice with fresh juice, in the same manner therefore as yeast, but with this difference, that it possesses an acid character. The fermentation already in progress in the preserved portion of dough, proceeds without interruption, although slowly, until it is required for use. During this time, which is shorter in towns, but in country places often extends to two or three weeks, an acid fermentation is added to the vinous, vinegar is produced and also lactic acid, which pass into the dough and the new bread. Persons with weak digestive organs are frequently unable to eat black bread in consequence, and this acid property is the only good reason that can be assigned to account for the difficulty with which it is assimilated.

It is obvious that in a mass thoroughly permeated by chemical activities, like leaven, these will not be easily subdued as long as the conditions remain unchanged. If the substances capable of undergoing the vinous fermentation are exhausted, the fermentative action will pass into the acetous and lactic modification, then taking deeper root and passing through the last stadium of stinking putrefaction, will not cease until all the constituents of fresh dough have been transformed into the last and simplest products of decomposition, which are mostly aeriform.

The stage of fermentation existing in leaven, when added to the fresh dough, is consequently of great importance to the baker, and anything beyond the vinous fermentation in the ferment, such as acidity, is very prejudicial to the bread, the chief mechanical object of the process, the evolution of gas, being then sacrificed. Although with the best of ferment, with fresh yeast for instance, the dough will gradually pass from the vinous into the acetous fermentation, yet the latter process is much more rapidly commenced when the ferment itself is already undergoing that change. The art therefore consists in retaining the ferment as much as possible in the proper stage, and this is easily attained with yeast, but is encountered by many difficulties in the case of leaven. The Germans call this latter process *Anfrischen*. It consists in mixing a quantity of the flour and water intended for bread at the next baking with the leaven; when the fermentation has raised this, another larger quantity is again added, proportionate to the mass of the leaven; this is repeated a third time, and oftener, until nearly the half of the flour to be converted into bread is in this state. The immediate object of this process is that of affording to the leaven a constant supply of the necessary saccha-

rine portions of new flour, in order that the vinous fermentation may predominate over the acetous. By this means several objects are gained. In the first place, the ferment is much more uniformly distributed through the dough than would have been possible had the small portion of leaven (about $\frac{1}{25}$th to $\frac{1}{5}$th of the bread) been kneaded at once with the whole mass of the flour; and again, this practice regulates the quantity of ferment to be added to the fresh dough. Thus, for instance, 1 lb. of leaven, added to 1 lb. of fresh dough, acts as a much more powerful ferment than if it were added to 100 lbs. of the latter; it is therefore more rational to allow the ferment to act gradually, and not at once upon the dough.

When the bakings are frequent, as in towns, the successive operations follow so closely the one upon the other, that no leaven is really obtained, but the prepared quantity of dough is separated into a larger portion for conversion into bread, and a smaller, which is set aside with a fresh portion of flour and water. In private houses in the country, on the contrary, where two or three weeks elapse between each baking, the leaven is allowed to remain for that period untouched, to be then mixed with the water and flour, which thus accounts for the sour country bread on the continent.

Whatever plan may be adopted in preparing the dough for fermentation, a thorough process of kneading is always essential, and must be carried out in a systematic manner, the dough is then allowed to remain in a warm place until the fermentative action is properly developed. The success of the process depends much upon the proportions in which the ingredients are mixed, and the proper quantity of water is very essential. These proportions are not fixed and constant, but vary with the quality of the flour, which again is dependent upon season, &c. In dry seasons the flour will bear more water than in wet, and a thorough process of kneading will also cause the dough to absorb a larger quantity than otherwise without becoming the less stiff on that account. The best flour takes up $\frac{3}{4}$ths, bad flour $\frac{1}{2}$ of its weight of water, and $\frac{2}{3}$rds is the proportion generally calculated upon.

When the fermentation has caused the dough to rise, it is then made into loaves, in which a tardy fermentation still proceeds. The bread is then placed in the oven.

No greater progress has been made in the improvement of the baker's oven than in the construction of mills, and the

oven discovered in Pompeii is precisely similar, even in the minutest points of detail, to the one at present in use in most country places. From the drawings, Figs. 56 and 57, which

FIG. 56.

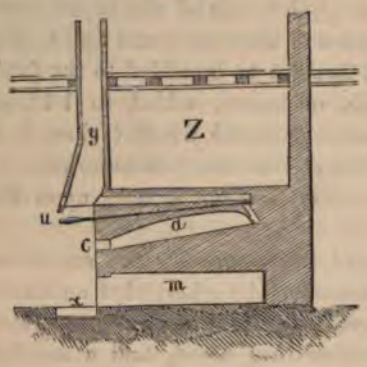
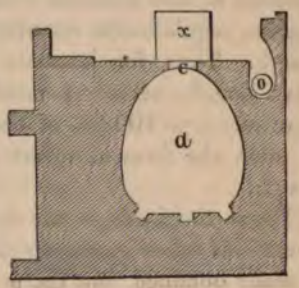


FIG. 57.



show the section and ground plan of a common baker's oven, it will be obvious that, although these arrangements completely fulfil the conditions required and bake admirably, they are attended with a great waste of fuel. The bed of the oven, *a*, where the baking is effected, is 10 feet wide by 12 feet deep.* The bed is egg-shaped, and is covered by a very low arch at a distance of about 1½ feet. The upward inclination is convenient for introducing the bread. The aperture *c* or mouth of the oven, is 2½ feet wide in front, it answers both for introducing the fuel and the bread. Three upright flues, *e*, *e*, *e*, are made in the back part of the arch, which, however, soon take a horizontal direction immediately above the arch, and approach the front of the oven, where they enter into the chimney, into which all the heat and vapours are discharged. A current is established on heating the oven, which, entering at the mouth, passes over the bed, through the three flues towards the front, and eventually escapes by the chimney. A damper, *u*, is placed in each of the flues for regulating this draught. The space *m* serves for holding the charcoal and ashes as they are withdrawn from the oven, and the space *Z* is the bakehouse, which is retained at the proper temperature for raising the dough by the spent heat of the oven and the chimney which passes up its side. The pit *x* enables the workman conveniently to place anything in

* These dimensions may vary within certain limits; they were taken from the oven of an ordinary town bakehouse.

the oven: *o* is a boiler for hot water. At the side of the mouth a narrow aperture is left for the insertion of a piece of burning fir-wood, which lights up the oven. This arrangement is more perfect than usual. In the country the ovens are seldom furnished with the dampers *u*, these being replaced by bricks or a cloth placed in the mouth of the flue. The spaces *m* and *Z* and the chimney *y*, are also missing. The bed of the oven may be made of clay, but is constructed better of bricks or hewn stone, which in many parts of Germany are supplied from the Westerwald. A soft kind of tuff is most applicable to this purpose. The ovens vary very much in size; some will contain as much as 150, 200, and even 600 lbs. of bread, but the treatment is the same in all. The draught in an oven being always inconsiderable, thin soft wood and brushwood is chiefly employed to heat it; or the wood must be finely cleft or some highly combustible fuel employed. The heat is communicated almost solely by the flame, and when that is extinguished and the charcoal only glows, it is withdrawn. The process of baking is always accompanied by the production of a small, but for many purposes very serviceable charcoal. This partly compensates for the cost of the fuel. In small ovens, and when very thin wood is used, the air which enters by the door of the oven is often sufficient, and the flues are not necessary, or are replaced by two small apertures above the mouth. In larger and superior ovens these cannot, however, be dispensed with. The hinder parts of the oven cool less slowly than those in the front near the mouth; the hot charcoal is therefore left at the threshold of the oven for some time before it is altogether removed, in order that this may be comparatively more strongly heated. In about an hour, or sometimes only half an hour, the oven has acquired the proper temperature, which is ascertained by the sparks which fly off from a piece of wood rubbed upon the bed, but is still too hot for baking. When the fuel and the ashes are removed, the bed of the oven is rubbed with a wet cloth, for the purpose of cleaning and cooling it. A trial is then made as to its fitness for baking by strewing some flour upon it, which should immediately become brown, but not black, which latter colour would indicate too high a temperature. If the oven is in proper condition the bread is now introduced, with such regard to regularity that no loaf remains longer in the oven than another, the one first inserted being also first removed. In Germany each loaf is rubbed over on the

surface with a wet brush before being placed in the oven, the loaves are thus made to shine on the outside, and the action of the heat on the outer surface is moderated. The time required to bake a loaf depends upon its size, and varies from one-half to two, or even three hours. All the apertures of the oven are closed during this time, excepting an occasional opening of the door to ascertain the state of the baking process.

The heat communicated by the fuel to the sides of the oven is thus imparted to the bread by radiation from above and by direct contact from below. A considerable quantity of heat still remains stored up in the sides of the oven after the removal of the loaves; this is either lost when the baking is finished, or applied to bake a second quantity of bread. The residuary heat in the oven seldom or ever suffices to bake the second charge thoroughly, an extra portion of fuel is required, or about as much as is consumed in half an hour; for the third baking still less is required, and so on until five separate charges have been baked, when the requisite quantity of additional fuel becomes constant and amounts to about $\frac{1}{3}$rd of the quantity originally consumed in heating the oven.* The foregoing facts clearly show that there is great economy as regards fuel when the baking is carried on without intermission, and that in country houses and private families, where the oven has to be heated for each separate baking, the greatest waste of fuel occurs. This has given rise, in Würtemberg and other parts, to the application of the principle of association in the erection of communal baking ovens, and many facts have been recorded respecting the economy of these. These ovens, which are built on a much more solid and advantageous plan, are either let to a baker, who charges $\frac{1}{3}$rd of a penny, and receives 1 or $1\frac{1}{2}$ lbs. of wood for each loaf, or the people bake themselves, and pay to the public officer who has charge of the oven about $\frac{1}{12}$th of a penny for every loaf of 6 lbs. weight. In several parishes the amount of wood saved by this practice has been valued at from £66 to £100 annually.

The oven arrangement above described is always accompanied with interruptions to the baking, from the necessity for fresh fuel, and this is of serious importance when an active trade is carried on. The want of an oven that could be heated in such a

* Schörg's oven, described at p. 196, requires for a single baking for 100 lbs. of bread $41\frac{1}{2}$ lbs. of wood; after four consecutive bakings, however, $6\frac{5}{7}$ lbs. of wood, or $\frac{1}{7}$th of the original quantity.

manner as to allow an uninterrupted succession of bakings to be carried on in it, led to the necessity of separating the firing altogether from the oven itself, and disposing it in such a manner that the oven should be constantly kept at the temperature most appropriate for baking.

In many countries, on the other hand, coal is the common fuel, and this cannot be well burnt upon the bed of an oven. Fig. 58

FIG. 58.

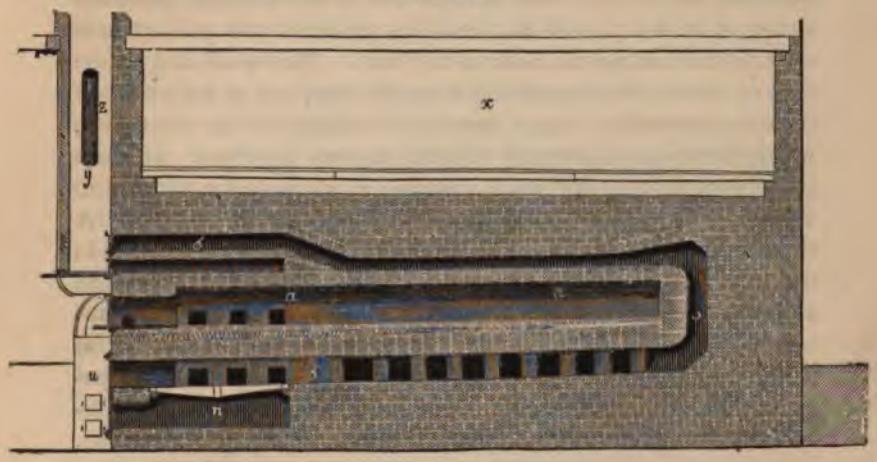
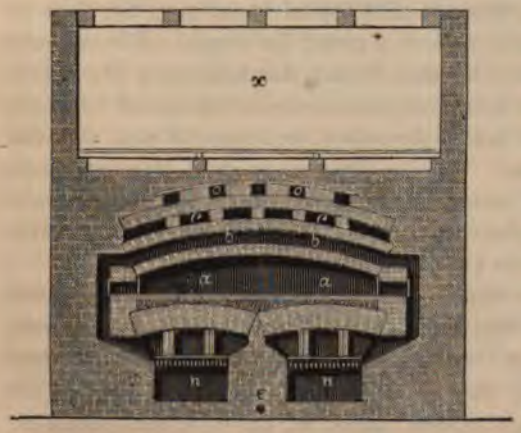


FIG. 59.



shows the oven of the military bake-house in Hanover, constructed for the use of coal as fuel, with a grate separate from the oven itself, and which can therefore be worked continuously. The baking space *a a*, with a slightly ascending inclination towards the back, is situated immediately above the two firings *n n*, which are arched over. These arches (Fig. 59) support the front part of the bed

of the oven, while the more extensive hinder part, or body of the oven, is supported by a great number of arches, the pillars or supports of which (40 in number) are erected upon the foundation wall, and form as it were (6) longitudinal channels perforated laterally, which rise perpendicularly at the back of the oven, returning over its top towards the front part, where they deliver the hot gases into the chimney *y*. The gases at this part of their course, are already cool, and incapable of communicating sufficient heat to the oven, besides which, the draught being the strongest at that part of the fire-space, an additional precaution is required for heating the neck of the oven. This is effected by the flues *i i*, which rise immediately from the fire-place on both sides of the oven (embracing it as it were) and terminate in the channel *b'*, which likewise communicates with the chimney *y* in front. The heat in the oven may be still more increased by allowing the flame from these flues *i i* to enter the oven itself through the apertures *s s*. A separate set of flues carries off the aqueous vapour from the bread; five iron pipes are inserted in the arch of the oven, which join in one common channel, ending in the flues *o o*. The channel *e* communicates with the air and conveys air to the two fires. A boiler *u*, situated in the side wall, may be heated by the same or by a separate fire, the smoke-flue from which is shown at *z*. The baking-space in this oven will accommodate 300 loaves of 7 lbs. each, or 2,100 lbs. of bread, consuming 6.4 cub. feet of coal; four bakings can be completed in a day, and only require a consumption of 16 cub. feet of coal; 100 lbs. of bread may therefore be baked at a cost of only $\frac{1}{3}$rd of a penny for firing. For the sake of comparison, it may be stated that the bakers in Darmstadt reckon a stack of wood for every ten or eleven bakings of 70 loaves of 5 lbs. each, which brings the cost of firing for 100 lbs. of bread to about 4 or $4\frac{1}{3}$ pence. In a communal oven at Deisslingen in Würtemberg 14,366 loaves of 9 lbs. each were baked during eight months with 16 klafters of pine-wood, which amounts likewise to a cost of 4 pence for every 100 lbs. of bread.

A patent has been obtained by Schörg of Munich for an oven constructed of iron, that combines the separate and double firing of that just described with portability. Clay gives out heat slowly and uniformly in a manner which is most desirable for baking, and for this reason there is an objection raised to substituting iron for it, which tends more to overheat the crust of the bread and render it black. The heat is, however, said to

be so regulated in Schörg's oven by flues, that it exerts precisely the same action as a clay oven, and causes a saving of 50 per cent in fuel. The oven is lighted by oil lamps. The conducting power of the iron is retarded by an accumulation of ashes.

Four aerotherme.—A few years ago, a baking oven invented by Jametel and Lemare was noticed, and its use recommended by the Société d'Encouragement in Paris. It belongs to that class of ovens which are not periodical in their action, but are at the same time very efficacious,* and is remarkable for the very original and beneficial manner in which the heat of the fire is communicated to the interior of the oven. The firing and its series of flues are, as it were, encased in a system of apartments, which are not in communication with it, and are filled with common air. The fire and flues are thus prevented from giving off heat to the outer mass of brickwork, which in the ordinary ovens becomes heated at a considerable expense of fuel. The heat is thus retained by the air of the apartment, to be by it communicated to the materials to be baked. The air channels communicate with the oven in such a manner that a circulation is established, the hot air replacing the cold air of the oven, which is conveyed by other channels to the heating surfaces, there to be re-heated and again circulated. The advantage of this plan consists in preventing the loss of heat, which is inevitable in ovens of ordinary construction. Coke is the ordinary fuel used. 260 loaves of 2 lbs. each are baked in an hour, but longer time is necessary when the loaves are increased in size. The coal ovens of England are similar to those described at page 192; they have, however, only one fireplace and grate, situated at the side of the oven, the flame from the fuel being allowed to enter and heat the baking oven. This flame is shut off from the oven and carried away by a flue when the baking commences.

Baking temperature.—The temperature to which the bread is exposed in baking is intermediate between 150° and 250° C. (302°—482° F.) In the four aerotherme it reaches 200° to 300° C. (392°—572° F.) These temperatures account for the failure which has attended the endeavours to heat ovens by means of steam, as a pressure of 4 to 15 atmospheres would be required to obtain the proper amount of heat.

* In an oven of this description in 5 times 24 hours 100 bakings were performed, or 23,900 lbs. of bread baked with 1,890 lbs. of coal, so that the cost of baking 100 lbs. of bread amounted only to something less than two-pence in Paris.

In modern times various improvements have been introduced into the processes concerned in preparing bread, some of which are still uncertain; others, on the contrary, have been carried into practice. The ordinary method of kneading dough has been objected to, as both uncleanly and prejudicial to health. Kneading is certainly subject to the former objection when, as is actually sometimes the case, it is effected with the naked feet, but it would hardly apply when the hands are used. The perspiration which may possibly become mixed with the dough during the process is certainly very inconsiderable. The kneading machine has been proposed to obviate the only real difficulty, which consists in the tedious nature of the operation when large quantities are to be prepared. Common experience suggests at once an objection to such machines, viz.: that no machine is capable of effecting fully what can only be judged of by the sense of touch; and this is the case in the process of kneading to a great extent, and is of importance, as the eye cannot penetrate into the interior of the dough. Differences in the consistence, foreign matters, grains, entire husks, dry lumps of flour are easily distinguished by the feel after a little experience, which is thus a safe guide to the baker. The gradual, systematic and sure mixture of water, yeast and flour, the addition or removal of one or other ingredient which may be requisite every minute, is accomplished with difficulty by a machine; so much the more as the doughy properties of the flour vary with the kind of grain, the season, the mode of preservation, &c., and in each case a different treatment is required, which is perceptible only to the touch of the workman. All kneading machines are either fixed troughs, in which the kneading apparatus is set in motion, or troughs which are moveable upon an axis with fixed kneading apparatus. In Cavallier's machine the trough is divided into two equal compartments, a roller revolves near the hollow cylindrical bottom, which extends the dough in the form of a thin leaf from one compartment to the next, and this is repeated several times by reversing the rotatory motion. The water is much less uniformly distributed through the dough by rolling than by any other method. In E. Clayton's machine, a trellis-work of knife-edges are made to cross each other in all directions in a cylindrical drum. In this arrangement the drum may revolve alone, the knives alone, or both may revolve in opposite directions. Another kind of kneading machine consists of a wooden drum, into which arms are fixed, stretching out towards the

centre, so that the mass of dough is torn up by them when the drum revolves. Others, again, consist of simple hollow drums, like that of Lambat. It is singular that the most natural and simple arrangement, that of kneading by means of hammers or stampers, as used in the powder-mills, has never been tried, although it would appear to be the best adapted for the purpose.

Alcohol a secondary product in baking.—When the raised loaf is placed in the oven, a certain amount of alcohol corresponding to the quantity of carbonic acid generated is contained in it; this, which is a valuable product, is dissipated by the heat of the oven. The enormous amount of bread that is baked in large towns—in London, for instance, 8.8 millions of cwts. yearly—would render the small amount of alcohol contained in it of sufficient importance to be worth collecting, provided this could be done sufficiently cheaply. All the experiments have however failed, and in the military bakehouse at Chelsea £20,000 have been expended in vain upon a collecting and condensing apparatus. Experiments have shown that 1 lb. of ordinary black bread in the state in which it is consumed (1½ days old) takes up a space of 60 cub. inches, 26 cub. inches of which consist of solid bread and 34 cubic inches of intercellular cavities, which contain (at 20° C.=68° F.) 0.976 gramme of carbonic acid. The formation of this gas by vinous fermentation supposes the presence of 2.16 grammes of crystallized sugar (grape-sugar) and the simultaneous production of 1.017 grammes of alcohol. When, therefore, in a baking of 400 lbs. of bread the alcohol brought into the oven with the dough is completely expelled and condensed, there would be obtained 0.81 lb. (of alcohol)=1.32 lbs. (60 per cent) of spirit, not quite 1½ pints (or 0.64 quart). A comparative result may be deduced from an experiment of Vogel, who obtained from flour containing 5 p. c. of sugar, bread containing 3.6 p. c.; if this experiment be accurate 1.4 p. c. of sugar must be lost by fermentation in the process of baking, or from every pound of bread 5.5 grammes, capable of yielding 2.58 grammes of alcohol and 2.47 grammes of carbonic acid. According to this calculation, there could not be more than 2 lbs. of alcohol or 3.7 pints of spirit obtained from 400 lbs. of bread. This calculation is obviously too high for either experiment. In the former, because the carbonic acid is at a temperature above 100° (212° F.) instead of 20° (68° F.), and therefore amounts to less; and in

the latter because a large quantity of alcohol must be lost before the bread is placed in the oven, and hence cannot amount to 2 lbs.

The immense consumption of bread gives rise to the production of an enormous quantity of alcohol, all of which is dissipated in the air—thus in London the quantity of bread consumed annually supposes the evolution of about 300,000 gallons of spirit, and the amount consumed in the German commercial league, about 7,500,000 gallons. The cost of collecting this would however exceed the value of the product, particularly as the bread cannot be baked in close distillatory vessels, but only in open ovens.

Substitutes for the fermentation of bread.—The above observations likewise afford the means of judging of that class of improvements which propose other modes of raising bread than that of fermentation. It was correctly premised that not only sugar was destroyed in this process, but likewise gluten, which acts as a ferment; as in the fermentation of sugar by yeast, both sugar and yeast are diminished in quantity. Upon this view, a portion of the nutritive substance of the bread is sacrificed to the mechanical operation of raising the dough. Henry called attention to this fact at the end of the last century, and considered the loss of sufficient importance to warrant the substitution of hydrochloric acid and soda for yeast. These two substances combine to form common salt, which is an essential ingredient in bread, and in doing this evolve carbonic acid. At a later period, 1837, this process was patented by Whiting. After remaining for some time unnoticed, the subject was again mooted by Dr. R. Thomson, supported by an observation of his own, that a sack of flour yields only 100 loaves upon the old plan, while upon the improved system it would yield 107 loaves; this loss, if the observations with reference to the amount of moisture are correct, exceeds the known quantity of sugar by 1 per cent, which therefore must be made up from the gluten. Another English statement accords a loss to the flour of 8 or 10 per cent. Both statements appear at first sight higher than the above calculation probably admits, and Frickinger found by direct experiment upon a large scale, that only $1\frac{1}{2}$ per cent more bread was obtained by the use of bicarbonate of soda than by fermentation, while the good quality of the bread—in contradiction to the opinion of the English, who are however bad bakers—was deteriorated by its use. The additional

1½ per cent is also far from sufficient to cover the cost of the new raising material.

The following receipts for the preparation of bread without yeast have been followed in England, but are strongly objected to by the medical faculty.

To make white bread:

Dressed flour . .	3 lbs.
Bicarbonate of soda .	9 drachms apothecaries weight.
Hydrochloric acid .	11¼ fluid drachms.
Water . . .	about 25 fluid ounces.

Another for unfermented bread:

Flour	1 lb.
Bicarbonate of soda . .	40 grns.
Cold water	½ pint.
Muriatic acid . . .	50 drops.

This yields a heavy bread, better adapted for biscuits.

Egg or baking powder:

Carbonate of soda . .	56 lbs.
Tartaric acid . . .	28 lbs.
Potato flour . . .	1 cwt.
Turmeric powder . .	¾ lb.

Another important point must also be kept in view, that the proper rising of the bread requires a slow but regular evolution of gas. The means proposed, as well as carbonate of ammonia, by itself or with tartaric acid, or bicarbonate of ammonia, all of which have been advocated, have one disadvantage in common, that they occasion a sudden but not continuous evolution of gas, so that there is great danger of the bread sinking again before it is placed in the oven. Alum and carbonate of ammonia have a better effect, which are decomposed into alumina, sulphate of ammonia and carbonic acid, but sulphate of alumina then remains in the bread, which may possibly exert a prejudicial effect upon the health of the consumers; the last portions of ammoniacal salts are also driven away with difficulty and leave a disagreeable flavour in the bread. The impregnation of dough with carbonic acid or with water previously saturated with carbonic acid yields a highly inflated bad dough.

Colquhoun mixed, for the sake of comparison, flour with water and flour with boiled starch, and after the addition of salt and yeast, baked them in the usual manner. He found that the bread obtained from the flour and starch paste had a very much sweeter taste than the other, and this is no doubt due to the gluten converting the dissolved starch much more easily into sugar than that which is entire. Others recommend $\frac{1}{20}$th part of the flour to be mixed previously with water and then made into dough with the rest, in order to obtain sweeter bread. The same method is followed in preparing bread from Indian corn, and the process is commendable and perfectly harmless.

Quality of good bread.—Well-baked bread should not possess an acid taste, nor a taste of spoiled meal; it should contain no lumps of flour nor of unraised dough. It should never be hollow, that is, the crumb should not be separated from the crust, nor filled with large holes, but the vesicles should be as numerous as possible and uniformly disseminated over the whole loaf. The crust must not be bitter or black, but brown and of an aromatic agreeable flavour.

Chemical process in baking.—In the examination of the change which takes place with the raised dough in the oven, a distinction must be made between the crust and the crumb. The heat of the oven only penetrates to a very slight depth below the surface of the loaf, but is there sufficiently intense, after the evaporation of the water, to produce a chemical change in the constituents of the flour. This is the point of the roasting process. In the interior, where the crumb is situated, a temperature not exceeding that of boiling water exists, as has been accurately ascertained, and no changes can occur there but those produced by the heat of the aqueous vapour. In the production of bread-crust the starch is first converted into gum, this is then further roasted, or submitted to a chemical process, of which all we know is, that it is the commencement of decomposition by means of heat, which is characterized in nearly all organic substances, even of the most different natures, by the appearance of a brown colour, an agreeable bitter taste and a much greater solubility in water. Reichenbach ascribes these properties to a peculiar substance called *Assamar*, the existence of which, however, as well as its nature, is not clearly ascertained. The products of the roasting process attract moisture, and hence it happens that the condition

of new bread, with its dry crisp outside and soft moist crumb, is after a short time entirely reversed. The crust of bread becoming daily softer, while the crumb becomes dry.

The changes which the substance of the flour undergoes in the crumb are very inconsiderable. Any portion moistened with iodine-water soon becomes of a deep blue colour. Water boiled with the crumb of bread likewise yields the characteristic reactions of starch. If the crumb of bread, softened with water at a temperature of 60° or 70° (140°—158° F.), is allowed to stand with a decoction of malt, after some time this reaction can no longer be observed, and a sweet syrup is obtained by filtration and evaporation. The same effect is produced by boiling with dilute sulphuric acid. If, lastly, the crumb of bread be dissolved in caustic potash and the solution treated with alcohol, a precipitate falls which swells up to a paste in water and exhibits a powerful reaction with iodine. In short, the starch of the flour is little, if at all, changed.

Wheaten flour, wheaten bread, rye flour and rye bread, all afford, when boiled with hydrochloric acid, the well-known violet colour which is obtained from albuminous substances. With the exception therefore of the coagulation of the albumen in the gluten, and the transition of the starch from the insoluble to the soluble or pasty state, there appears to have been no change of importance. The sides of the vesicles composing the crumb of bread must be viewed as a very uniform and intimate mixture of starch paste with gluten. All that has been adduced respecting a combination of these two from various quarters is without foundation; they may be easily separated by a current of cold water. The more starch there is contained in any flour, the easier the bread becomes doughy under similar treatment.

During the process of baking the dough becomes much lighter from the loss of water; when therefore the bread is required to be of a certain weight, as is everywhere obligatory by law, this loss must be calculated upon in forming the loaf; in small loaves the loss is proportionally greater. Prechtl states from experiment, that loaves which after baking and drying,

Weigh . . .	1 lb.	2 lbs.	3 lbs.	4 lbs.	5 lbs.	6 lbs.	8 lbs.	12 lbs.
Require that an extra weight be taken in the dough of . .	6 oz.	8 oz.	12 oz.	11 oz.?	12 oz.?	16 oz.	20 oz.	24 to 32 oz.

According to Accum, 7 lbs. of flour yield 10 lbs. of dough and 8¾ lbs. of bread. According to Hermbstädt, 3 lbs. of flour yield 4 lbs of bread. In the military bakehouse at Hanover 8 lbs. 5 oz. of dough are required for a 7 lbs. loaf.

An admixture of certain substances materially influences the amount of water retained in the bread after baking.

According to experiments made for the Analytical Sanatory Commission, published in "The Lancet:"

Bread made with 2 lbs. of flour, and the necessary quantity of water and German yeast, had acquired or retained on removal from the oven 8½ of water.

The same quantity of flour, with an addition of 2 scruples of alum and ½ an oz. of salt, retained in the loaf 9½ oz. of water.

In another loaf, in which the alum and salt were in the same proportions, but ½ lb. of the wheat flour was replaced by rice flour, nearly 10 oz. of water were retained. After twenty-four hours' exposure to the air, the weights of the above loaves were as follow:

	lbs.	oz.	drachms.	scruple.
1st Loaf . .	2 .	7 .	7 .	—
2nd „ . .	2 .	9 .	3 .	1
3rd „ . .	2 .	10 .	— .	1

The first had lost 5 drachms, or more than ½ oz.

The second less than 5, and more than 4 drachms.

The third less than 4 drachms.

So that it appears, the power of retaining water is much increased by alum, and still more by rice flour, and that the loss during the first day in a 2 lb. loaf is about ½ oz.

Rye bread retains more moisture and remains longer moist (new) than white bread.

According to Dumas, the dough prepared for the *pain de munition* contains 37 per cent of moisture, that for other bread 45½ per cent. A sack of flour (=318 lbs.) yields from 102 to 106 loaves of 2 lbs. each.

In the military bakehouse on the Quai de Billy, in Paris, 5,088 lbs. of flour are daily kneaded with 3,600 lbs. of water and 8 lbs. of salt; from these 7,454 lbs. of bread=146 per cent of the flour, are baked daily in 11 ovens, with a consumption of 1,760 lbs. of birch-wood.

In England, the vast quantities of bread required for supplying the navy and shipping generally, which must be of such a character as will keep, has given rise to a very extensive manu-

facture of biscuits. These are partly made by hand, and partly by machinery.

In the hand process, the dough having been prepared in the usual manner, is deposited on a strong wooden table, called a *break*, where it is submitted to great pressure by the *break staff* upon which the workman sits, and jumping upon it in a very uncouth manner, so contrives that his whole weight is brought to bear consecutively upon the entire surface of the dough. The latter is then placed upon a moulding board in front of the oven, cut into slips, and divided into lumps of the proper size for a biscuit. The circular form is then given it by the hand, and one biscuit being laid upon another the pair are pierced with holes by an instrument, called a *docker*, which stamps at the same time the maker's name, or any devise upon the biscuit. The biscuits are then thrown with great dexterity by another workman, called the *furner*, into the oven, those introduced first, and which must consequently remain longest in the oven, being made somewhat larger. The oven is of wrought iron, in shape resembling the segment of an ellipse, and has often an area of 160 square feet. The furnaces are on the sides of the oven, and are fed with flaming coal, the flame being conducted by flues all round the oven. The whole oven being filled in a few minutes with biscuits, is closed for about ten minutes, when it is again opened, and the biscuits withdrawn. In the biscuit bakehouse, at Her Majesty's Victualling Office, Deptford, the quantity baked each time is about 112 lbs. of biscuit in the form of dough, which yields 100 lbs. of baked biscuit. The number in this weight is about five hundred and eighty, so that there are about six biscuits to a pound.

Each baking is called a *suit*, and each oven can bake twelve suits a-day with five hands employed in the various operations, but on an emergency as many as sixteen or seventeen suits may be finished. With twelve ovens, at the average daily rate, there are 14,400 lbs., or eighty-five thousand biscuits, baked at Deptford.

In addition to the far greater quantity of bread that can be made by machinery in a given time, which during times of war is of great moment, the process of kneading can also by its means be more uniformly carried out, and the water being thus equally distributed through the entire mass of dough no portions of the biscuit are overburnt, on account of containing too little water, nor are others rendered *hard* and *flinty* by being imperfectly baked, at

the same time a greater uniformity in thickness can be given to the biscuits, which also greatly tends to prevent flintiness. The first process of mixing flour and water by machinery is conducted in a horizontal cylinder, 3 feet 3 inches in diameter, into which the meal is thrown, while water is supplied from a cistern above it. A rotary shaft, armed with knives working in a horizontal direction, passes through the centre of the cylinder, and being set in motion by the engine, prepares in the short space of two minutes as much as 5 cwts. of perfect dough. The lower half of the cylinder can be removed from the upper by means of a wheel and pinion, and the dough thus removed is thrown under breaking rollers to be kneaded.

Two breaking rollers are employed weighing 15 cwt. each, they are set in motion by a two-throw crank shaft, by means of connecting rods and pendulum, passing backwards and forwards over the dough for a few minutes they render it perfectly equal in consistency. The dough is then cut into pieces 18 inches square, placed on boards, and passed under other rollers, which reduce it to the proper thickness for biscuit. In this state it completely covers the board upon which it was passed under the rollers, and is then brought under the cutting and stamping plate of cast-iron, which is furnished with spikes or pins for perforating the biscuits. It is there cut into an exact number of hexagonal tables, the plate being moved up and down in a vertical manner upon the sheet of dough. The biscuits are now ready to be placed in the oven. By machinery of this description twelve thousand biscuits, or 1 ton of bread may be manufactured per hour, as at the Royal Clarence Victualling Yard, at a cost of four-pence per cwt.

Adulteration in bread.—Many cheaper substances may be substituted for flour, either wholly or in part as a matter of private economy or taste, or famine and general poverty may induce the use of such adulterations. In the latter case, the subject becomes one of public interest, and is of the utmost importance to the general weal; as such, it deserves to be noticed in this place. In many cases the quantity only is increased by the additions, without any reference to the quality of the product, and this at once condemns the practice; the additions are either of an indigestible nature and deficient in nutritive power, such as sawdust, bark, husk and wheaten straw, paper, bone-dust and several kinds of lichens; or they are such as are not altogether

innutritious, but are repulsive in their nature to the taste and smell: such are the raspings of dried hides, cabbage-stalks and brewers' grains.

Besides these ill-adapted substances which have been recommended at different times, we have still to consider the case when flour is adulterated with other cheaper productions, which are however in themselves nutritious. It must be borne in mind that these additions never entirely replace the nutritive properties of wheaten flour, and the object sought in using them is to lower the price of the flour or bread by employing such matters as in themselves are of little or no value. In times of scarcity the evil is only remedied when the bread is not only made cheaper, but equally nutritious, and roots or tubers, such as potatoes and turnips, are frequently employed for such purposes. Potatoes contain 75 per cent of water, and only 2.43 per cent of blood-forming constituents, while the flour of rye contains 15 per cent of water and 16 per cent of blood-forming ingredients; these facts prove that 20 parts by weight of potatoes contain as much nourishment as 3 parts by weight of rye flour, and the addition of potato meal will only constitute a real saving when, for an equal weight, the price of the potato is less than $\frac{3}{20}$ths that of rye flour. When, therefore, a malter (150 lbs.) of rye flour costs 56 shillings, and the malter (200 lbs.) of potatoes costs 11 shillings, there is no longer any real economy in using the latter. All other provisions rise in value with the price of corn. Turnips only contain 1.5 per cent of blood-forming ingredients, they are therefore of still less value than the potato, and can only be employed with advantage when an equal weight costs only $\frac{1}{11}$th the price of corn. Potatoes are added to the dough of flour either in the boiled state (when it would be simpler not to bake them with the bread, but to eat them with it), or are grated raw and kneaded up with it after the juice has run off (in this latter case, nearly all the nutriment is lost with the albumen of the juice). Flour mixed with $\frac{1}{5}$th or $\frac{1}{3}$rd of potatoes has a good appearance and flavour, but is very prone to become firm and doughy, adhering to the knife when cut. For this reason potato bread cannot be so wholesome a food as bread made from flour; and still less, because the admixture of potato meal interferes materially with the original favourable mixture of ingredients. Suppose $\frac{1}{3}$rd of potato has been baked with the bread, then three loaves of this bread contain as much nutriment as two loaves of pure bread; while, however, the blood-forming constituents of

the latter constitute $\frac{1}{5}$th of the whole, in the potato bread they only constitute $\frac{1}{6}$th. The deception arises from the large amount of water, and this applies in the same manner to beet-root, which has latterly been recommended by Payen, mixed with 2 parts of flour. Mixed in these proportions the two afford a less heavy bread than potatoes, but this is not much cheaper in reality than that from the unmixed flour. In rice and Indian meal the amount of starch is so great that these are equivalent in nutritive value to dry potato flour. The leguminous fruits, on the contrary, particularly peas, have a very high nutritive value and improve the quality of the bread. These alone will not produce bread or a porous cake, but flour will bear a very large addition of them, and affords then an excellent bread, which is very common about Giessen and other parts of Germany, and is always desirable when peas are sufficiently low in price or when it is wished to consume them in this form. As 3 parts by weight of peas are as nutritious as 5 parts of grain, an addition of the former to bread will be economical when their price is under $\frac{3}{5}$rds that of corn. An actual saving is only really effected by adding to bread those substances which in the ordinary course of things are not sufficiently marketable, such as bran and the refuse of malt.

If the bran is baked with the flour or unboltered meal is used, the bread is then uselessly overcharged with bran, as is the case with the *Pumpernickel* of Westphalia, and is indigestible, although the entire nutritive constituents of the bran are thus turned to account. This is the case in a less degree when bran-water (infusion of bran) is employed to make the dough, a practice followed in many places, and which yields a more digestible kind of bread. Malt refuse, or malt dough, consists of the fine dusty floury particles of barley malt which are deposited on the top of the grains when the wort is made. It contains a portion of the barley flour which is lost to the brewer, and is chiefly used as fodder for cattle. When the amount of water contained in this substance is not excessive ($\frac{3}{4}$ of its weight) it affords an excellent bread mixed with equal parts of flour (Essig, Schlossberger.) In the fresh state, it contains from 4 to 8 per cent of starch and 21 to 26 per cent of nitrogenous matters; it is consequently, when the water is omitted, nearly equal to the leguminosæ in nutritive properties. The breweries of Bavaria alone produce 30,000 cwts. of this product annually, and 7 lbs. of it afford, according to Essig, 4 lbs. of bread. Oil-cake, which has recently been proposed as an admixture with bread,

contains a large quantity of casein (29 per cent), and would in itself be as beneficial an addition as pea-flour, if it were not for the intolerably rancid oily taste which it possesses and which it is difficult to remove.

Bread lichens.—In seasons when the corn is obliged to be harvested in wet weather, the bread which is prepared from it has a strong tendency to become mouldy. Thus, for instance, the bread distributed amongst the troops in Paris, in the year 1841, was observed to contain throughout its mass, in all the crevices, a red growth, which proved, when examined by the microscope, to be the vegetation of a minute lichen, *Oidium aurantiacum*, the locality of which is chiefly in the husk. It spread itself over the other portions of the bread so much the more rapidly, the more husk there was incorporated with it. Bizio observed this lichen as early as the year 1819.

Dumas states that 100 parts by weight of ordinary wheaten flour yield 130 parts of bread. The bakers in the neighbourhood of Giessen calculate that a malter of grain which, after deducting the bran and the perquisite of the miller, affords 150 lbs. of flour, will produce from fifty-two to fifty-four loaves of 4 lbs. each, or about 140 per cent of mixed black bread. Dumas estimated the amount of water in bread, from two to twelve hours old, at not less than 45, and not more than 51 per cent; Schlossberger found from 50 to 52 per cent of water in bread made with malt-dough.

The amount of nitrogenous matter found by Thomson, in

Naumburg bread, flour of 1841 (dried) . .	16.49
Dresden white bread	14.30
Berlin bread of the year 1842	14.21
Glasgow bread, made with soda and hydrochloric acid in place of yeast	13.39

Experience has shown the bakers that the soft, doughy consistency and the bad colour of bread prepared from inferior flour may be obviated by the addition of mineral salts to the dough, the oxides of which are precipitated in an insoluble state upon the substance of the flour. In Belgium, blue vitriol is universally employed for this purpose (Kuhlmann). Although the quantity employed is extremely minute, yet the practice is of a more reprehensible character than that of using alum, which is often employed in this country.

STARCH.

Among the long series of intermediate forms through which the food of plants passes before it attains its final object in the vegetative economy, there are several which appear to be peculiarly useful under all circumstances, not only in the different organs, but in the most various species, races and families of plants. *Sugar*, and more especially *starch*, among others to be noticed, belong to this class, as has been clearly proved by the characteristics of the farm produce described in the preceding pages. When the term starch is applied in its most extended chemical sense, the cases in which it has not been met with in the organs of plants are much more rare than those in which it has been found. Many observations appear to prove that starch is laid up as a store of nutriment in the plant at certain periods of its development, to be assimilated and applied to various purposes at others. Thus Fritzsche has shown, that at the germing period, the starch-grains in the potato appear eaten away, until they at last entirely disappear. The same has been observed in the grains of corn. The starch which can generally be obtained from unripe fruit in considerable quantity, vanishes altogether as the fruit ripens. The varieties of starch which chemists have found in the roots of the Elecampane, of the Dahlia and in Iceland moss, are merely interesting in a scientific point of view; the only variety of any practical importance is that contained in grain, in the leguminous fruits, &c., in the form of small organised microscopic granules. Starch was known to the ancients under the name ἄμυλον, (*i. e.* the unground, or meal by nature); they made, however, but little use of it. It is chiefly contained in bulbous roots and in seeds, but has also been observed in numerous other roots, in the stems of our common trees and in the pith of the palms. Starch has been found in plants belonging to the families of the grasses: the *Solaneæ*, *Leguminosæ*, the *Lilies*, the *Cacti*, the *Najadæ*, *Chenopodiæ*, *Orchideæ*, *Oxalideæ*, in the *Bineweed*, in the *Menispermeæ*, and many other plants. As generally obtained, in the pure state, it exhibits the appearance of brilliantly white flour, which, under the microscope, is seen to consist of innumerable small grains, perfectly colourless and transparent, and varying considerably in size, according to the source from whence they are derived. Although the grains are of variable sizes in the

same organs of the same plant, yet according to Payen, in order to make up the thickness of a line, the following number of grains from the different sources must be laid side by side:

Starch from:	Number of grains.	Starch from:	Number of grains.
Potato	13—18*	White bean	50
Arrow-root	18	Pea	50
Sago (commercial)	36	White wheat	55
Fresh pith of sago palm	33	Indian corn	83
Sow-bean	27	Millet	250
Lentil	69	*Chenopodium quinoa*	1250

The individual grains of starch do not appear uniform in structure throughout, as is a drop of glass, but are made up of concentric rings, which all coincide or run together in one single point (hilum) of their periphery. More accurate observations have proved that this appearance in the grains is due to their onion-like structure; they are constituted of a series of layers ranged round a common germ. Their form is generally spherical or tuber-like, often somewhat lengthened or flattened, more or less irregular, as is the case with entire potatoes. In leguminous fruits, they are often bent inwards, while in wheat the grains have a more lenticular shape. Sometimes, when a large number are congregated together in one cell, the mutual pressure flattens them into polygons, as in Indian corn, where the grains are so densely packed that the whole takes the appearance of a horny integument. The chemical and physical properties of starch are intimately connected with its structure; the most striking peculiarity lies in the outer layer or coat, which, although exhibiting similar characters in many respects to the internal layers, yet offers much greater resistance to most reagents, and particularly to water. When a single grain is pressed together between two plates of glass, and a drop of cold water is added to it, the internal layers are seen to dissolve, leaving the outer coat unaffected. This latter constitutes $\frac{3}{10}$ths per cent of the entire weight of the grains. If starch is rubbed up with cold water like a pigment, the same separation takes place, the internal mass swells up, and the outer coats remain unchanged. The inner substance is therefore protected from the the action of cold water by the outer skin, and this property enables the starch to be separated by washing from the other substances with which it occurs in the organs of plants.

* According to Fritzsche's measurements, 30 to 600.

Of all (not including exotic) plants, the potato, and the varieties of corn are alone sufficiently cheap and productive to be used as sources of starch upon a large scale. Wheat, which is the only grain employed for the purpose,* affords a more finely granular product than the coarse starch from the potato. Although both are equally pure, yet wheaten starch is better suited to many purposes, and is considered of better quality. A glance at the characters of wheat, and of the potato (described at pp. 85 and 104), will make it evident that from the former the starch has to be separated from a large quantity of a tough doughy gluten, and consequently with much difficulty; while in the potato it is enclosed in cells which likewise contain other substances, but in lesser quantity, and all in solution. The cells have in this latter case only to be broken up that the starch may be floated away by water, and afterwards separated from the diluted juice by deposition. It is hardly necessary to state, that those species of the potato are selected which contain the largest amount of starch, as far at least as these can be obtained.

The relative amounts of starch in the different cereal grains and in the potato have been estimated as follows by Krocker:

CEREAL GRAINS.

	Starch.		Nitrogenous matters.
	I.	II.	
Wheaten flour	65.21	66.16	19.16
Rye	61.26	60.56	11.94
Oats	37.93	36.90	18.00
Barley	38.62	37.99	17.81
Barley meal	64.63	64.18	—
Buckwheat	43.80	44.45	9.96
Buckwheat meal	65.05	—	6.89
Indian corn	65.88	66.80	14.68
Indian corn meal	77.74	—	13.66
Rice	85.78	86.63	7.40
Beans	37.71	37.79	28.54
Peas	38.81	38.70	28.22

* Rice is now largely employed in this country in the manufacture of starch, as will be described further on.

POTATOES.	Starch.		Nitrogenous matters.
	I.	II.	
Blue potatoes . .	23.20	22.80	2.37
White ditto . . .	18.14	17.98	2.49
„ „ . . .	16.48	16.09	—

The differences in the potatoes are due to the different amounts of water which were greatest in those containing the least starch.

In fact, the separation of the starch from the potato involves a disintegration of the cells, but before this is effected, all foreign matters, as dirt, &c., must be carefully removed from the tubers, as these would injure the machines in which the process is effected, as well as the product.

Potato-starch.—The construction of the machines employed for washing and tearing up the potatoes, has been borrowed from those employed for similar processes in the manufacture of sugar from beet, as will be described and figured hereafter. The washing drum is, in fact, a roller consisting of two bottoms or discs, upon which, at regular distances from each other, laths are nailed. This roller is immersed to about one-third of its depth in a trough full of water, which flows away as it becomes impure, and is replaced by fresh water. The drum revolves slowly on its axis, so that the tubers roll one upon the other, and become cleansed by attrition. From the washing roller they are placed in the rasping apparatus, constructed upon Thierry's principle, where they are pressed against a rasp-like surface, consisting of saw blades arranged in great numbers and at short distances from each other over the whole curved surface of a roller. The revolution of this roller converts the potatoes almost instantaneously into a uniform pulp. The pressure occasioned by the weight of the potatoes against the rasping surface is quite sufficient to reduce them to this condition. The action of this machine is most perfect, when no cell remains unopened, which at the same time is not torn up into very small fragments. This effect is produced, partly by the pressure exerted by the potatoes themselves upon the rasping surface, and partly by the velocity of the rotation, both of which should bear a certain relation to each other. If the pressure is too great, the teeth of the rasp will rub off the layers of the potato two thick, and many of the cells will be left entire; too little pressure and velocity occasion a loss of time and power. A cylinder of the ordinary dimensions of 2 feet in diameter, should

make from six hundred to nine hundred revolutions per minute. A cylinder of this kind, 1.6 feet long, will reduce to pulp 14 to 15 hectoliters = (38 to 40 bushels) of potatoes in one hour. The pulp is conveyed from one of the rasping cylinders to the apparatus for washing.

Cylindrical machines.—In small factories, this washing was effected originally in an upright cylinder, consisting of two compartments, the bottoms and sides of which were composed of wire gauze, the meshes of the lower compartment being very much smaller than those of the upper into which the pulp was first introduced, and this system is even now sometimes practised. A stream of water supplied through a rose, and with the help of a rotating brush, washed the starch and the finer portions of the pulp from the upper into the lower compartment, the closer meshes of which only allowed the starch with a very small quantity of the finest cellular remnants to pass through; the passage of the starch was also here accelerated by a brush, as in the upper sieve. The coarser particles alone were left. From each compartment the refuse was removed by a special door. The wire cylinder itself is surrounded by a casing, which prevents the liquid containing the starch from being thrown about. Collecting below with the finest particles of pulp, the starch is conducted to the depositing troughs. These washing cylinders work easily and with rapidity, but a loss of time is occasioned as they only admit of small quantities being worked at once, and interruptions to the process are of frequent occurrence, as it is necessary to remove the pulp at stated intervals; the pulp is likewise not thoroughly exhausted, and much starch is lost. These objections have been remedied in the washing apparatus of Lainé, in which the sieves are more numerous, and of more variable degrees of fineness, and are arranged one after the other upon an inclined plane, in such a manner that the lowest and widest sieve receives an uninterrupted supply of fresh potato pulp, while, from the uppermost and finest, the residues are as regularly removed. At the same time the washing current of water is conducted in an opposite direction from the highest to the lowest sieve, so that the residues, the more they are exhausted, come into contact with purer water. The details of the arrangement will be better understood by reference to the drawings, Figs. 60 and 61. A flat scaffolding *a a*, consisting of beams, and a wooden bottom gives a firm support, with a proper inclination to the whole apparatus. The separate parts

of the scaffolding are held together by bolts. The bottom *e e*, thus forms with the long and narrow ends a kind of long flat box, which is separated by the cross-bars *i i i* (Fig. 61) into eight compartments; each compartment is covered above by a frame-work, in which a wire-work sieve is stretched, of these there are altogether eight. Immediately over the sieves, in a direction from below upwards, slides a double-link chain *b b* (Vaucauson's) of the same construction as the watch-chains, the opposite links of which are connected by means of cross pieces. The pulp, which falls into the box *m* from the tearing apparatus, and there overflows the inclined board *n*, is drawn upwards at that point in a gradual manner by the cross-bars of the chain, is pushed over the eight sieves one after the other, until at length it falls beyond the uppermost sieve into the trough *l* placed below it. In proportion as the pulp advances, it is washed by water, so that it arrives entirely exhausted in *l*. That the motion of the pulp may be uninterrupted, constant and steady, the chain is endless, and forms a closed ring, double the length of the entire scaffolding. At the two ends, it is wound round the rollers *b' b'*, which are moved by machinery. The chain, after moving over the sieves in an upward direction, returns in a contrary direction to the first roller, in returning it is supported by the ledges *f f*, which are borne by the uprights *g*. Above the whole, as far as the third compartment, the tube *q* extends, which emits fine jets of water from a series of small apertures throughout its whole length; this water drops with the remainder of the starch from the almost exhausted potato pulp through the meshes of the sieves to the corresponding compartments. From thence, it is employed to wash out the ascending unexhausted pulp in the following manner; a series of pipes arranged externally at the sides, and not shown in the drawing, convey the liquid containing the starch from the second compartment to the fourth sieve, a similar pipe from the third compartment leads to the fifth sieve, another from the fifth to the seventh, and so on, and finally from the last compartment by means of a trough (also not shown in the drawing) to the depositing boxes. The drawing shows that the whole arrangement is double, *i. e.*, consists of two chains running parallel with each other, comprising two series of sieves and compartments. The machinery as shown in the drawing is 56 feet long; this length has been extended to 80 feet in some cases, to ensure the entire exhaustion of the pulp. An inclined surface of such extent is very

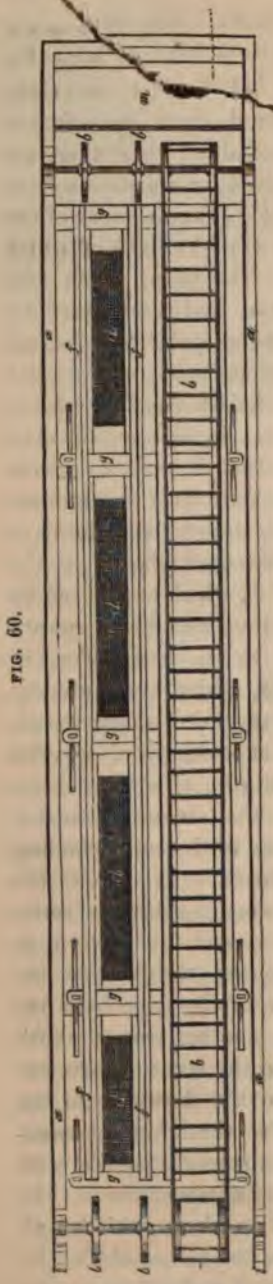


FIG. 60.

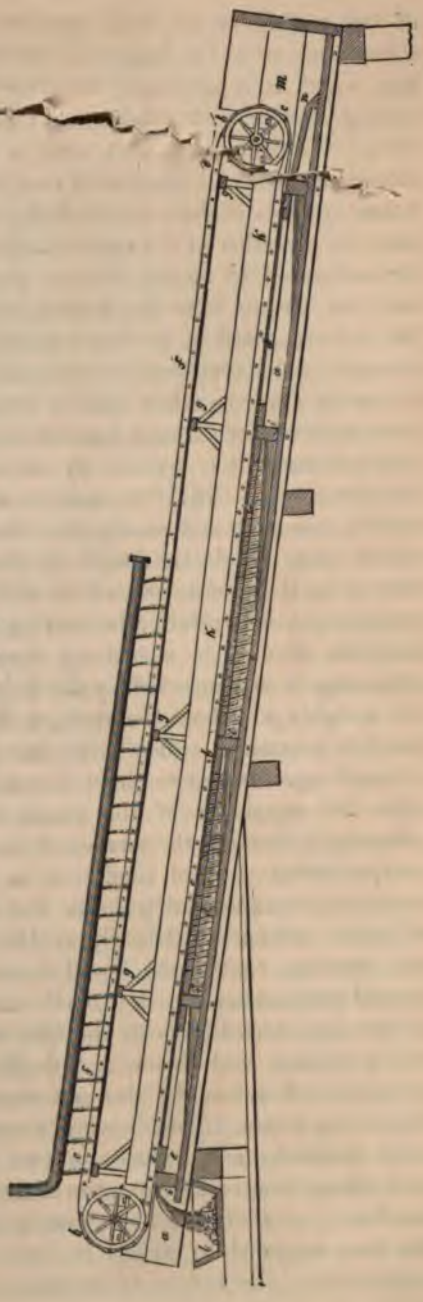


FIG. 61.

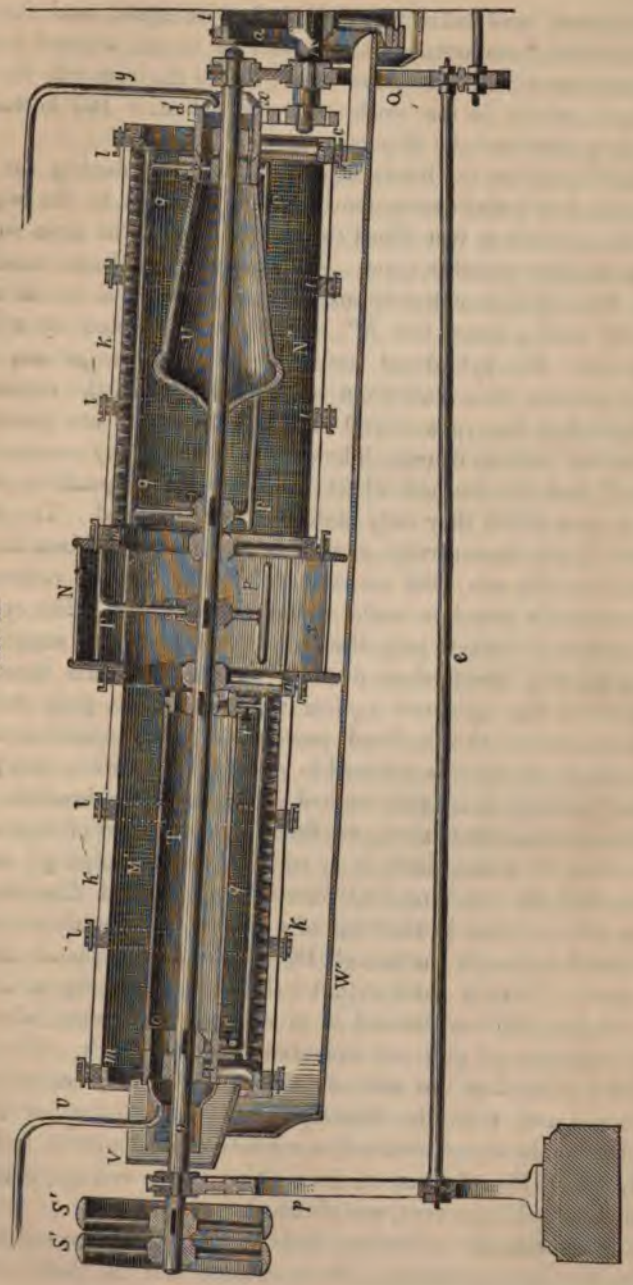


FIG. 62.

inconvenient, and takes up a great deal of space, and for this reason others have arranged the surface of sieves, without lessening their extent, one above the other; this is the case with Dailly's machine, which in ten working hours, exhausts 160 hectoliters (= about 440 bushels) of potatoes.

Huck's machine.—Others again, without abandoning the real advantages of Lainé's arrangement, have returned to the original cylinders, which in fact afford the largest amount of sieve surface in the smallest possible space. Amongst these is Huck's machine, (Fig. 62.) This machine comprises two cylindrical sieves, an upper one *M'* and a lower one *N''*, which are connected by a brass drum *N*. The cylindrical sieves consist of the rings *mn*, upon which wooden rims *k* are fixed by the bolts *l*. In the interior of the cylinders the rousers and brushing apparatus are placed, as well as the feeding drums. The sieves are rotated by means of the axle *A'* and the toothed wheel *x*; they are independent of the axis *o*, over which they only slide, but are not fixed. The drums *T* and *U*, on the contrary, as well as the stirrers and brushes, are fixed upon this axis, and are rotated by means of the rollers *S'S'* in an opposite direction to the motion of the sieves. The cylinder *M'* receives the potato pulp through *V*, while water is supplied by the pipe *v* to the feeding drum *T*, whence it spirts through a number of fine apertures against the sieve. The pulp flows in consequence of the inclined position of the apparatus slowly towards *N*, where it is agitated in passing by a stirrer, and passes on to *N'*, where it is again worked with rousers and brushes. The meshes of this latter sieve, are finer, and composed of brass wire; the drum *U* which feeds it is supplied by the pipe *y*; and in order that the water may be forced in an upward direction, the drum *U* is widened in the form of a cone. The liquids containing the starch collect in the trough *W'*, and flow from thence through the gutter *Q* to a third cylindrical sieve, containing no stirrers or brushes, but constructed of much finer wire gauze, where the last fragments of pulp are separated from the starch. This third cylinder is fixed at the axle *A'*; the end of it is indicated by the letters *a* and *t* in the drawing. The sieve-rollers of Huck's machine make about twenty-five revolutions in a minute, and work daily 30,000 lbs. of potatoes, from which, on an average, 5,100 lbs. of starch, or 17 per cent, are obtained.

The contrivances of Vernies, Stolz and St. Etiene are constructed upon the same principle. It is obvious that the different sieve

arrangements are dependent for the amount of work they perform upon the effectiveness of the rasping cylinders, and that the amount of starch will depend upon the extent to which the cells of the potato have been torn up and destroyed by the teeth of the rasps. It is calculated that from 2 to 4 per cent of starch generally remains in the residues. These latter amount to 15 per cent of the potato; about 5 per cent cellular tissue and starch, the rest being water. They are applied as additions to cattle fodder; their value as such is, however, not great, as the water which has left them carries with it the whole of the albumen of the potato.

Völker started the original idea of disintegrating the cellular tissue of the potato in a more perfect manner than is effected by the rasping cylinders, by the chemical effects of a kind of humus-formation or *rotting* process. Crushed or rasped potatoes are converted, when exposed to a temperature of 20° or 30° C. (68°—86° F.) with a sufficient quantity of water into a soft, brown, doughy mass. The result of this decay is the destruction of the cellular structure by reason of a chemical decomposition, which, however, does not extend to the starch when the process is kept within certain limits. This process of rotting is, however, not practicable, on account of the time it requires, and the fine state of division to which the cellular substance is reduced preventing its ready separation from the starch.

Purification of starch.—All these arrangements, whatever their construction may be, afford a milk-white liquid, in which the starch and some other substances are held in suspension, whilst others again are dissolved. The further operations are intended for the purification of the starch, and subsequently to dry and fit it for sale. The reservoirs which receive the liquid, can be emptied of the latter after standing for a few hours, when all the heavier particles have been deposited. This liquor can be used with advantage for moistening manure heaps, on account of the albuminous matters it contains. The deposit is immediately stirred up with fresh water, is then left a moment at rest, until stones, earth, and similar substances have fallen to the bottom, when it is again drawn off through a fine sieve, and this operation is repeated several times, with finer sieves each time. After these strainings the liquid containing the starch is allowed to stand in a depositing reservoir, until the starch has not only settled down, but has caked together, when the last portion of water is drawn off. The uppermost layer of the deposit is whitish-

yellow in colour, and muddy; it contains the residual portions of the impurities, and is removed. The remainder forms a cake of pure starch, which is separated into small pieces, and removed. When not immediately used (for instance, in the production of dextrin and sugar) it requires to be dried. The cakes are then broken up into still smaller fragments, and placed in drainers, constructed in a conical form of wire gauze of a very fine kind.* A large quantity of liquid drains away, so that the starch is afterwards in the form of compact loaves, still containing however a considerable quantity of moisture; one portion of this is removed by absorption, the loaves of starch being arranged side by side upon a floor of gypsum, where they acquire more consistence, and can then be placed upon the laths of a drying scaffolding, exposed to a good current of air, but protected from dust, for about six weeks. The starch dries with so much difficulty, that even after that period it contains two-fifths of its weight of water, which cannot be easily removed without the aid of artificial heat. Drying chambers are used for this purpose heated by a current of hot air, the temperature of which can be carefully regulated to a certain pitch. The large quantity of water which the starch retains would cause it to be entirely converted into paste if the heat exceeded 40° C. (104° F.), and the produce would then be spoiled. The danger of this is lessened as the starch dries, but even at last the temperature must not exceed that of boiling water. When fully dried, and in a fit state for sale, the starch still retains from 8 to 15 per cent of moisture.

Wheat-starch.—Rye and barley are seldom used for the production of starch; of the cereals, wheat is generally preferred. These are used in the form of grains, as a coarsely-ground powder, or as flour; the various refuse products of the mill, as bran, coarse flour, &c., can likewise be employed. The facts already enumerated at page 84 prove that the amount of starch in the cereals varies with the soil upon which they are grown, as well as with the climate. These variations are so considerable, that an intelligent manufacturer will necessarily pay great attention to them.

* It is evident, from the above description, that sieves are the most important utensils in the manufacture of starch, and these are of all sizes and degrees of fineness. The durability of brass wire, and its freedom from rust, fit it more especially for the manufacture of the gauze sieves, the degrees of fineness of which are designated in commerce by numbers. The cyphers in each number indicate how many meshes are contained in a square inch of surface.

The hard Italian and North African wheat are less adapted to the manufacture of starch than the varieties of wheat from colder countries. With reference to the latter, from wheat grown upon unmanured land, for 6 parts of starch 1 part of gluten has to be separated; while from wheat manured with human urine, in order to obtain an equal quantity of starch, 5 parts of gluten must be removed. All the difficulties in the manufacture of starch are connected with the character of the gluten, which of itself is insoluble in water, and when not of such a nature as to agglutinate into balls, remains in flocculent particles which are intermingled with the starch.

The two methods in use for separating starch from grain are essentially dissimilar. According to the older barbarous process, in order to separate the starch, the other important and valuable kind of food with which it is associated is uselessly destroyed in a manner which infects the atmosphere of the neighbourhood with the odours accompanying putrefaction, and the gluten can only be got rid of in the form of the soluble products of its decomposition. The more modern and rational process aims at separating the two principal ingredients of the grain, starch and gluten, in such a manner that both shall be unchanged, and in a state fit for consumption.

Older process.—The older process varies according as the grain is previously coarsely ground or not. The bruising or coarse grinding is carried out either in bruising mills, like those used in breweries, or in the ordinary flour mill. The bruised grain must then be mashed, or caused to swell with as much water as will render it, when after twenty-four hours it is fully permeated by the water, thin, limpid, and not doughy. It must here be especially noticed that pure water is not applicable for this purpose, as fermentation would then take place too slowly; the acid water, on the other hand, impregnated with fermentable matters from the fermenting tuns (to be hereafter described) effects this in a much shorter time, and exerts the same effect as yeast. It communicates its own state of decomposition to the mashed grain after a short time. Meantime the sugar dissolved in the water is made to undergo the vinous fermentation; the alcohol formed is speedily converted into an equivalent of acetic acid; while at the same time the decompositions are multiplied; lactic fermentation, and then putrefaction, follow. In the beginning, when the evolution of gas is more copious, the solid particles rise to the surface, and carried

up by the bubbles of gas, form a thick scum, which requires to be often thrust down, and mixed with the liquid. The entire process lasts one, two, and often three weeks, according to the temperature, and is ended when the thick mass clears to a light yellow, and rather acid liquid, in which the husks, a portion of the gluten and the starch, are suspended. The liquid contains, besides carbonic acid, sulphuretted hydrogen, lactic acid, acetic acid, different salts, ammonia, gum, and gluten in solution. The presence of the latter, as the main object of the whole operation, is due not so much to the solvent action of the acids in the liquid, which are too dilute and in too minute quantity to exert such an action, as to the property of the gluten itself of becoming liquid before undergoing putrefaction. Pure gluten set aside with water, loses its usual characters after fourteen days, and forms a thick, somewhat acid liquid, which may be used as glue, and has quite the appearance of that substance. The finest particles of the gluten are dissolved, which is so much the more desirable as these are the most difficult to separate from the starch. A considerable portion of the starch is also transformed by the fermentative process into gum and sugar.

The separation *or treading* is effected in strong hempen or linen sacks, of a certain thickness, which are nearly filled with the fermented mash, and being tightly tied together at the mouth are trodden in a tub with the feet. The milky liquid which exudes is drawn off after some time, and water is substituted in its place, the treading being constantly kept up as long as the liquid from the sacks has a milky appearance, or contains starch. After three or four additions of water this point is attained, and the mixture is separated into a mass of gluten and husk as residue and a liquid, which in addition to starch contains in solution a small quantity of gluten, some husk, and the substances enumerated above.

Several expedients are resorted to for purifying the starch. The liquid is first passed through fine sieves, which allow the starch and the finer impurities to pass through, keeping back the husk and coarser pieces. The subsequent operations consist in suspending the starch with the finer portions of fibre in water, and allowing the starch to settle down, in consequence of its greater specific gravity, in depositing tuns, while the glutinous particles form a brown-grey layer above it. When the acid water has been drawn off, the upper impure glutinous layer is removed (which is purified in a separate vessel), and the starch is again stirred up

with fresh water, the process being repeated as long as that which flows off is sour and stinking. The starch cannot be obtained perfectly pure in this manner, but as the particles of gluten lie at the top in a tolerably well-defined layer, this can be easily removed, or is allowed to dry upon the starch, when it separates as a skin in consequence of the greater contraction it undergoes in drying. The drying process is conducted upon the same principles, and essentially in the same manner as was the case with potato-starch. When towards the end the cakes of starch in the drying chamber are turned with their flat sides opposed to the current of hot air, and the drying progresses uniformly from one surface to the other through the entire mass, the latter contracts so uniformly, that regular cracks or crevices are produced, which separate the cake into small columns resembling basaltic pillars; in these small columnar strips it is frequently found in commerce.

The remains of the gluten are always foul and stinking when obtained in this manner, and can only be used as food for pigs; when separated before fermentation has taken place, they can be used as fodder for other animals.

The method of preparing starch from unbruised grain is much more like Martin's process, to be hereafter described. The unbruised, softened grain is sometimes squeezed between rollers, at others this is done simply by treading: in every case this operation precedes the fermentation. A less decomposed residue is thus obtained (gluten and husk), and a glutinous water, containing starch, which is set aside to ferment, and that process being finished, is purified and treated in the same manner as the liquid which was first obtained from the sacks.

The glutinous residue obtained by this method is not adapted to human food on account of the husk that is mixed with it, but may be used for fattening cattle, a branch of industry which should always be connected with the manufacture of starch, if the latter is to be profitable.

Martin's process.—According to the most recent improvements of E. Martin, flour is preferred to crushed or uncrushed meal, and this is made up into a stiff dough with two-fifths of its weight of water; the meal must be left in contact with the water for about two hours, that all the parts may be thoroughly softened before it is subjected to washing. A trough, covered with a wire sieve of No. 120, is used for the washing, above which a pipe and a cock

afford a constant supply of water. The end of this pipe is terminated by a rose containing forty fine apertures, in order to divide the current of water into as many small jets. A piece of dough, about the weight of 10 lbs., is treated each time upon the sieve: when the water is allowed to run, a milky liquid flows through the sieve, and the operation is aided by kneading. If great pressure were exerted in kneading, portions of gluten would likewise pass through; these however agglutinate together after a time, and the kneading may then be carried on more vigorously. As soon as the water passes through clear the washing is finished, and a second portion may be placed upon the sieve.

The liquid containing the starch is generally allowed to ferment during twenty-four hours, in a warm place, in order to separate more easily the particles of gluten with which it is always mixed. It is then allowed to settle. The purification and drying is effected in the same manner as before.

Besides the white starch, a portion of an inferior character is always obtained, which cannot be well separated from the light fibre (*amidon gras* or *noir* of the French). The latter is firmer, less easily broken and discoloured; affords however a very excellent paste, wherever the pure white colour is not an object.

In using Martin's process, which is gradually superseding the old method in Germany, rather more than a fourth part of the meal is obtained as gluten, in a fresh, undecomposed state, containing about 38 per cent of water. Some have proposed that this should be baked into bread with inferior flour, or with potatoes: experience has proved that an artificial bread, prepared from potato-starch and gluten, is very insipid, and difficult to raise; while a mixture of boiled potatoes and gluten affords a very palatable food. Others have recommended the use of this gluten as a kind of ferment, in place of yeast; and others again that it should be mixed with wheaten flour, in order to produce, by an artificial method, the rich glutinous meal of southern countries for the preparation of macaroni. Macaroni only softens, without dissolving and losing its form, when prepared from flour containing a large amount of gluten. All these propositions have to contend with the same difficulties in practice. The gluten is extremely subject to decompose and decay, and cannot be appropriated as rapidly as it is produced in the starch manufacture. The common methods proposed for drying the gluten, which are difficult to carry out, on account of its tenacity and the tendency

it has to retain moisture, are too complex, and require too much manual labour. The process proposed by the brothers Viron, called the *granulation* of the gluten, appears however to be successful.

Granulation of gluten.—The gluten, mixed with an equal weight of flour, is stretched out in long strips, which are prevented from adhering to each other by a sprinkling of flour. These strips are brought between two rollers, the smaller of which is covered over its whole surface with little pegs, and moves with much greater velocity than the larger, and are there separated into small elongated pieces. These pieces are likewise kept separate by sprinkling flour over them, and can then be easily dried by a hot current of air, in drying chambers, at a temperature of 30° or 40° (86° to 104° F.) They then form a mass of grains, which are separated by sieves into four different sizes. The granulated gluten, which is a mixture of gluten with flour, can be preserved for any length of time, and contains about 70 per cent of gluten, and consequently more than double the quantity in ordinary flour, and in the same chemical condition. In this form it is very applicable for making soup for transportation, and as a stock provision. The process for obtaining starch upon Martin's plan, combined with that of Viron, for converting the gluten into a valuable product, is obviously the most rational, as no loss of any useful ingredient of the flour is sustained.

A new preparation from wheaten flour has lately been introduced by Mr. Bullock, as a very concentrated and easily-digested food, peculiarly adapted for invalids and infants. He calls this preparation Semola, and guarantees it to contain 50 per cent of gluten, or the blood-producing element of the grain. The semola is in rounded grains, resembling sago in appearance, only smaller; it is prepared by washing out the greater portion of the starch from wheaten flour, and rapidly drying and granulating the residue. The preparation is directed to be consumed in the form of gruel, made with milk or water. It has no disagreeable taste or flavour, as is usually the case with the preparations of gluten, and is no doubt a highly nutritious food.

Flour was at one time wasted in the form of hair-powder, and for this purpose the finest wheat-starch was employed, with the loss of the whole of the gluten, which could only be used as a bad fodder for cattle.

Starch from rice.—Rice contains a larger quantity of starch in

proportion to the other ingredients than any of the cereals (*vide* pp. 212 and 213), and processes for obtaining it from that grain have been patented both by Messrs. Jones and Berger.

On Jones's plan the rice grains are first steeped in a solution of caustic potash or soda, containing 200 grains of alkali to the gallon, 100 lbs. of rice being macerated with 50 gallons of this lye for about twenty-four hours. The solution is then drawn off, and the grains are washed with 100 gallons of water, which is strained off through sieves. The grains being thus softened are ground to meal under rollers or edge-stones, the meal being passed through sieves, and the residues reground, until nothing remains on the sieves but a little husk. 100 lbs. of the meal thus prepared is then macerated and well stirred up with 1000 lbs. of the alkaline solution; the stirring must be often repeated during the first twenty hours, and the whole is then allowed to settle during one hundred and seventy hours. The lowest deposit consists of fibrous matter with a little starch; above this a layer of pure starch is deposited. The gluten, and traces of other matters remain dissolved in the brownish-yellow turbid lye. When the whole of the starch has settled down, the alkaline liquor is removed with a syphon without disturbing the starch, and the sediment is well agitated with twice as much water as there was of alkaline solution. The greater portion of the fibrous matter settles down in the course of an hour, when the starch, still held in suspension, is drawn off into another vessel, passing through a fine silken sieve to remove particles of husk. The fibrous matter is again washed with water, in order to separate a little starch that is mingled with it, and the washing is repeated until nearly the whole has been thus removed. The starch is allowed seventy hours to settle, the water is then drawn off, and the starch is mixed with blue colouring matter (smalt) if required, drained, dried, and prepared for sale in the usual manner.

Berger's process consists in softening the rice grains by soaking them in water, grinding and sifting the ground meal, until it all passes with water through a sieve containing sixty meshes to the inch. The flour being allowed to settle, and the water drawn off from the deposit, a solution of 7 lbs. of carbonate of soda in 3½ gallons of water is poured over it and stirred for half an hour; the rice is left in contact with the solution for fifty or sixty hours, being stirred every four hours. The whole is then allowed to settle for twelve or eighteen hours, when the solution containing the gluten

is drawn off by means of a syphon. This process is repeated once, and the residue after being well washed with water is passed through one of the usual sifting apparatuses employed in the manufacture of wheaten starch. This separates the heavier particles, which are again treated with a solution of carbonate of soda. The starch being allowed to settle from suspension, is washed, dried, and packed as usual.

In order to soften and disintegrate the rice grains, it is found more economical, before grinding, to moisten them well with water, and in some instances to allow them to heat, or undergo incipient germination, by being heaped up moist together, and frequently turned. The grains after this treatment, which lasts from four to six days, become so soft that they can be easily crushed to powder between the thumb and finger. When ground in this state, and well steeped and lixiviated in water, the starch may be separated from the gluten which remains suspended, or in solution in the water without the application of alkali; but the two processes combined are found most efficaceous in practice. Berger recommends the use of artificial ultramarine in place of smalt, for giving to starch the blue colour required in commerce.

Nash has proposed the use of ammonia in place of potash or soda in these processes, and Rehe the application of a temperature of 160° to 180° F. to the entire or unground rice for two or three hours previously to the application of an alkaline solution.

Starch from the horse chesnut.—Hedenus and Flaudin have proposed the production of starch from the horse chesnut, which amongst other amylaceous and albuminous substances is said to contain 25 per cent of this substance. The bitter principle in the chesnut can be removed by alkali, and the following process is said to afford a product, which cannot be chemically distinguished from starch obtained from other sources. The chesnuts are thrown into boiling water, skinned and grated; the grated mass is then well mixed and kneaded with soda (1 lb. to 100 lbs. of the pulp), and the starch subsequently obtained from it by washing in the ordinary manner. Water alone is said also to remove the bitter principle, but a sharp taste then remains attached to the starch, which can only be removed by alkali.

Arrow-root.—The snow-white powder known as arrow-root, and at one time most erroneously considered the very essence of nutrition, and particularly recommended as food for infants, is a very pure kind of starch prepared in the West Indies, particu-

larly in Jamaica, from the root of the *Marantha arundinacea* and *Indica*, plants belonging to the family of the *Scitamineæ*. The name was first applied to the root from its supposed efficacy in curing wounds. The starch is contained in the joints of the rhizome, or underground stem, being deposited in a number of very minute cells.

The following account of the mode of preparing this arrow-root is given by Pereira:

"The starch or fecula is extracted from the roots (tubers) when these are about ten or twelve months old. The process is entirely a mechanical one, and is performed either by hand or by machine.

"In Jamaica it is procured as follows: The tubers are dug up, well washed with water, and then beaten in large deep wooden mortars to a pulp. This is thrown into a large tub of clean water. The whole is then well stirred, and the fibrous part wrung out by the hands and thrown away. The milky liquor being passed through a hair sieve or coarse cloth, is suffered to settle, and the clear water is drained off. At the bottom of the vessel is a white mass, which is again mixed with clean water and drained; lastly, the mass is dried on sheets in the sun, and is pure starch.

"In Bermuda the roots are first deprived of their paper-like scales, and then rasped by a kind of wheel rasp, and the fecula well washed through sieves, and carefully dried.

"Upon the Hopewell estate, in the Island St. Vincent, the carefully skinned tubers are washed, then ground in a mill, and the pulp washed in tinned-copper cylindrical washing machines.

"The fecula is subsequently dried in drying houses. In order to obtain the fecula free from impurity pure water must be used, and great care and attention paid in every step of the process. The skinning or peeling of the tubers must be performed with great nicety, as the cuticle contains a resinous matter, which imparts colour and a disagreeable flavour to the starch. German silver palettes are used for skinning the deposited fecula, and shovels of the same metal for packing the dried fecula. The drying is effected in pans covered by white gauze to exclude dust and insects."

This species of arrow-root is distinguished from every other by the form and peculiarity of its granules as viewed under the microscope. These are more or less oblong and ovate; sometimes mussel-shaped, or even almost triangular, the larger ones being marked by concentric lines; at the large extremity of each a

distinct spot is visible, ordinarily considered to be a cavity, and denominated the "hilum;" this spot is sometimes circular, but most frequently is seen as a short sharp line running transversely across the granule.

Another species of arrow-root is obtained, in the East Indies, from the *Curcuma angustifolia*, a plant of the family of the *Zingiberaceæ*. It is prepared in a similar manner as the Marantha arrow-root, from which it can however be easily distinguished by the form of the granules under the microscope. The "hilum" being placed at the narrow extremity of the granule and the lines, which are often very indistinct, forming only segments of circles. Both these varieties are known in commerce as Indian arrow-root, and are distinguished from the arrow-root of Tahiti and other South Sea islands, which is obtained from the *Tacca pinnatifida* and *oceanica*. Pereira thus describes the preparation of the fecula: "At Tahiti this is prepared by washing the tubers, scraping off their outer skin, and then reducing them to pulp by friction on a kind of rasp, made by winding coarse twine (formed of the cocoa-nut fibre) regularly round a board.* The pulp is washed with sea water through a sieve made of the fibrous web, which protects the young frond of the cocoa-nut palm. The strained liquor is received in a wooden trough in which the fecula is deposited, and the supernatant liquor being poured off, the sediment is formed into balls, which are dried in the sun for twelve or twenty-four hours, then broken and reduced to powder, which is spread out in the sun to dry.

Tacca arrow-root has generally a slightly musty odour, and is easily distinguished from the other varieties by the small size of its granules, and the position of the hilum under the microscope. The grains of all the three varieties have a distinct form. In South America, starch is chiefly obtained from the roots of the Yucca, *Jatropha manihot*, fam. of the *Euphorbiaceæ*, or *Manihot utilissima*, the plant which yields the tapioca of commerce. The granules of this variety resemble those of the Tacca, but are considerably smaller; a large proportion exhibit a circular outline, as seen in the field of the microscope, and the hilum is generally fissured. The Yucca is the same root as that from which the Indians prepare a kind of bread and cake called cassava, which is insipid, but admits of being preserved for a length of time.

* Ellis states that the rind of the root is scraped off by a cowrie shell, and the root grated on a piece of coral.

Arrow-root is also obtained from the tubers of the *Arum maculatum*, the common "cuckoo fruit," "wake robin," "lords and ladies;" it is prepared chiefly in Portland Island, hence it is generally called Portland arrow-root. The tubers of this plant being very acrid, the starch requires extra washing.

Genuine arrow-root being an expensive substance, it is extensively adulterated in this country with cheap substitutes, the chief of which are potato-flour, sago-meal, and tapioca-starch.

Sago.—The starch from the pith of palms, or sago, is brought into commerce in a peculiar form, which is the result of a special mode of preparation. The real plant which affords sago is still a matter of dispute, but it is certain that many species are capable of yielding starch; amongst these are *Sagus Rumphii*, *Cicas inermis* and *revoluta*, *Coryota urens*, *Borassus Gomato*, several species of *Zamia*, *Corypha*, and *Mauritia*. The starch is contained in the palms in the soft, pith-like substance of the stem. In these monocotyledonous plants the pith is more abundant than in our trees, and comprises the chief bulk of the entire stem, which, from the rapid growth of the palms, often attains the thickness of the human body in seven years. A single stem of this kind is said to yield 3 cwts. of sago, which is obtained by a method somewhat similar to the older European method of producing starch. The pith being separated from the stem is washed upon sieves, and the starch collected after being purified by a process of elutriation in depositing vats. The starch is then exposed to the air for some days, until it can be easily crushed without falling to powder. This *granulation*, as it is termed, is performed on sieves in such a manner that the little lumps which pass through the meshes fall upon a hot plate of copper. Each lump is thus converted into paste, the starch granules immediately swelling up in the hot liquid, and these dry up into the irregular, roundish, translucent masses which constitute the sago of commerce.

A distinction is made between white, red, and grey sago; the red colour is attributed by Planche to the external integument of the starch contained in certain kinds of palms, and this is often converted by the process of manufacture, or by natural change, into the grey modification. The essential property of sago consists in its swelling up in hot water or in soup, without melting, the separate little lumps remaining entire, and forming translucent stiffly gelatinous, but not slimy globules. Six varieties of sago are distinguished by Planche:

Source.	Colour.	Quantity of water absorbed in softening.
From the Maldives .	Grains, mostly red, some white . .	150 p. c.
„ Sumatra . .	„ white, or dirty-white . . .	134 „
„ New Guinea .	„ brick-red, or lighter . . .	121 „
„ the Moluccas .	Red variety	130 „
„ „ „ .	Grey „	109 „
„ „ „ .	White „	164 „

A considerable quantity of sago is now made from potato-starch, in the same manner as that from the palms. The red variety is imitated with bolus. It is difficult to communicate the same degree of hardness to potato-sago, as is possessed by the foreign product; it has a greater or lesser tendency to become pasty when boiled.

Chemical constitution of starch.—Starch contains a very small quantity of wax or fat which does not properly belong to its nature, and must be viewed as an impurity. Thus Payen found $\frac{1}{200}$th part of a thickish, easily solidified oil. Excepting some minute traces of mineral salts, derived from the water employed in washing, no other foreign substance has been observed in starch; it has been repeatedly investigated with the greatest care with reference to its elementary composition. The following table exhibits a selection of the most important results obtained from the examination.

The following elements have been found in pure starch from:

	Carbon.	Hydrogen	Oxygen.	Observers.
Wheat	44.26	6.70	49.04	Strecker.
Rye	44.16	6.64	49.20	„
Buckwheat	44.23	6.40	49.36	„
Indian corn	44.27	6.67	49.06	„
Rice	44.69	6.36	48.95	„
Peas	44.33	6.57	49.09	„
Lentiles	44.46	6.54	49.00	„
Beans	44.16	6.69	49.15	„
Potato	44.25	6.67	49.07	Berzelius.
Horse chesnut	44.44	6.47	49.08	Strecker.
Dahlia roots	44.13	6.56	49.31	„
Unripe apples	44.10	6.57	49.33	„
„ pears	44.14	6.75	49.11	„
Marantha arundinacea (root) . .	44.40	6.18	49.42	Prout.
Root of yams?	44.20	6.50	49.30	Ortigosa.
Root of elecampane (Mulin) . . .	44.75	6.20	49.05	Mulder.
Iceland moss	44.71	6.26	49.03	„
Calculated from the combinations of starch with other bodies . .	44.44	6.17	49.38	

These results afford positive proof that starch from the most various sources is composed of the same elementary ingredients in the same proportions, and that the oxygen and hydrogen are in precisely those relative quantities in which they unite to form water. This applies to starch in the perfectly dry, but unchanged, state, in which, however, it never occurs in commerce.

The following is the composition of the varieties of starch, as they occur in commerce, as analysed by Richardson.

Water in samples as sold in retail, dried at 212°.

Arrow-root . . .	16.10 per cent.
Sago	16.96 „
Tapioca	14.69 „
Tous les mois. . .	19.04 „
Rice	14.84 „
Semolina . . .	14.78 „

Composition of the same dried at 212°:

	Arrow-root.	Sago.	Tapioca.	Tous les mois.	Rice.	Semolina.
Carbon	43.71	44.01	43.74	41.99	43.21	45.90
Hydrogen	6.35	6.27	6.41	6.44	6.83	6.91
Oxygen	49.74	49.53	49.71	51.42	49.44	46.39
Ashes	.20	.19	.14	.15	.52	.80
	100.00	100.00	100.00	100.00	100.00	100.00

When moist, freshly prepared starch is placed upon bibulous paper or upon gypsum, 45 per cent of water will still remain in it when nothing more is absorbed. In a dry room, or kept exposed to the air at 20° C. (68° F.) starch retains about 18 per cent of water. Dried over sulphuric acid *in vacuo*, about 9 per cent are retained, and it is only by the aid of a temperature of 120°—125° (248°—257° F.) that the entire quantity of moisture can be removed from it without decomposition. When starch dried in this manner is exposed to air that has taken up as much moisture as possible at a temperature of 20° (68° F.), it absorbs in a few days 35 per cent of moisture. Starch is therefore a very hygroscopic substance. Amongst the chemical properties of starch, there is one of special importance, its reaction with iodine, which has been principally instrumental in aiding its examination. This property is worthy of the greatest attention, for without a knowledge of it the following statements would be unintelligible. Ordi-

nary commercial starch produces with iodine, either in an aqueous or alcoholic solution, or as gas, a beautiful intensely blue compound. When the iodine solution is concentrated, the depth of colour almost amounts to black, and the iodine penetrates into the very centre of the grains. This colour is the common test for starch. In alkaline liquids it does not occur at all, or only in a very imperfect manner, in consequence of the superior attraction of these substances for iodine. The colour vanishes gradually with the action of light, the iodine combining with the hydrogen of the water; it is also destroyed by a boiling temperature, but reappears when the liquid cools.

Formation of paste.—Starch is perfectly insoluble in alcohol, ether, as also in cold water, a property which it owes to the integuments surrounding the separate granules and to which allusion has already been made. When heat is applied to the water, a different effect is produced. Starch mixed with 15 parts of cold water, and the milky liquid gradually warmed, becomes partially transparent at 60° (140° F.), and completely so at 70° (158° F.) The whole then forms a thick mucilaginous liquid, of a turbid appearance, which on cooling coagulates to a thick jelly or *paste.* The formation of paste is more fully developed as the temperature rises to the boiling-point, and is completed when the liquid is no longer rendered perceptibly more transparent. The paste is thicker in proportion, as a lesser quantity of water is employed, and the jelly stiffer on cooling. When a large quantity of water is used, for instance, 100 parts, the liquid is thin and not mucilaginous, nor does it coagulate on cooling, but the unaltered skins and imperfectly dissolved particles soon settle down. By regulating the quantity of water, any degree of consistence may be obtained. If so little water is employed that the starch cannot dissolve in it, or, if the liquid is not well stirred, lumps are formed containing entire starch granules in their interior; these dissolve with difficulty, and are easily burned. Starch that has taken up 35 per cent of moisture, forms itself into a paste immediately when strewn upon a plate heated to 150° (302° F.) This is not the case with air-dried starch containing 18 per cent of moisture. The proportion of 1 part water to 3 parts starch is therefore sufficient to disintegrate the starch granules; but a real paste cannot be produced without more water.

The action of hot water upon starch has been minutely studied, step by step, under the microscope, and it has been observed that

the granules first swell in consequence of the water permeating the external coat, and combining with the contents in the interior. This extension progressively increases until the skins burst. In the granules of younger growth, which possess weaker skins, this occurs at a temperature of 55° (131° F.), and proceeds until at a temperature of 72° (162° F.) nearly the whole are destroyed. The different thicknesses and densities of the outer skins afford an explanation for different kinds of starch requiring different temperatures in order to be converted into paste.

When starch-paste is pressed between linen, the greater portion is left in the form of jelly; if the strained liquid is evaporated to the same consistence and again pressed, a similar effect is produced, liquid also passes through, which again exhibits, under similar treatment, the same result. When starch is boiled to a very thin clear liquid, and poured upon a filter, a portion only very slowly passes through. Both the liquid and the jelly are coloured blue by iodine, the former yielding a blue solution. The blue-coloured substance is gradually deposited from this liquid, and small quantities of earthy salts greatly accelerate this deposition, for instance, when $\frac{1}{10000}$th part of chloride of calcium is added, a deposit or gelatinous mass of blue flocculent particles separates, leaving a colourless solution above it.

If the uninjured spongy radicles of a living plant are immersed in starch-paste, the water only is absorbed by the roots, while the starch forms a coating on the outside. If starch-paste is allowed to stand for some time, fissures are produced in its substance, in which water collects. Frost effects a similar result, only in a more decided manner. When frozen starch-paste is thawed, a large quantity of water flows from it, and a cohesive jelly is left, which can be removed in a single piece. The water can be expressed from this jelly by a slight pressure, leaving a spongy mass, or, when the jelly was more concentrated, a substance resembling the pulp of paper, which has all the properties of starch, is coloured blue by iodine, &c. It is indeed starch, altered only in form by the consecutive action of heat and cold.

All these phenomena lead to the conclusion that paste is not an actual solution, but contains the substance of the starch (called Amidon, or Amidine) in a swollen condition, which, however, when highly diluted, approaches the state of solution. Starch-paste may therefore be practically viewed as a solution of the less dense matter of the starch granules holding the skins and

denser particles in suspension. The skins of the starch granules ultimately swell up, and are dissolved by protracted boiling, as is the case with the substance of the cellular matter of the potato. The skin has been separated as much as possible from the more soluble amidon, and each has been separately analyzed with the following results:

	Carbon.	Hydrogen	Oxygen.
The dense part of potato-starch yielded: . .	44.49	6.13	49.38
„ soluble „ „ „ „ . .	44.27	6.27	49.46
„ „ „ of arrow-root „ . .	44.30	6.20	49.50
The entire substance of starch (compare p. 231) .	44.44	6.17	49.38

The skins, the amidon, and the entire starch, have therefore precisely the same elementary composition. This chemical substance or starch, as contained in paste, is precipitated in combination with the bases of several salts; for instance, with oxide of lead, from which the amidon can be again separated perfectly unchanged. From the nature of these compounds, it has been concluded that the composition of starch must be expressed by the formula $C_{12}H_{10}O_{10}$.

Paste, when dried, forms a yellow, translucent mass, consisting of flexible pieces, which swell up slowly in cold, and rapidly in hot water, from which they are again obtained by evaporation.

Conversion of starch into gum and sugar.—Starch or amidon is very subject to chemical transformation, under the influence of reagents. The changes which it undergoes may be considered from two points of view: they either entirely alter the chemical nature of starch, and give rise to new compounds which have no very close relation with it, or they change its nature in such a manner as to retain the fundamental chemical constitution of the vegetable body, and produce new compounds, which however stand in the closest possible relation to amidon. To use a simile, these two kinds of transformation may be aptly compared to alterations in an already finished edifice. If the building is entirely thrown down, and the building materials employed for the construction of sheds, stabling, &c., the process would resemble the first case. If the building remain entire in its principal parts, and internal or external changes are carried on about it, this would correspond with the second. The changes of the first kind, among which are those produced by a high temperature and carbonization, are

of little technical importance; while the second are of the greatest interest, as they are the foundation of a number of branches of manufacture, and tend to explain the processes concerned in vegetable and animal life. Nearly all weak chemical agents convert starch or amidon into two new products, the one of which is a species of gum, *starch-gum* (*British gum*), the other a kind of sugar, *starch-sugar*. According to circumstances, the one or other of these is produced, or often both at once.

Formation of sugar and gum from starch.—Gum is the name applied in chemistry to a series of substances derived from vegetables which are characterised by negative properties, such as the absence of crystalline form, colour, smell, and taste, by their insolubility in alcohol, ether, and oils. These form transparent masses, possessing conchoidal fracture, and are sometimes accidentally coloured. Some—for instance, gum tragacanth—only swell up in water, like amidon; others are soluble in water, forming a thick, adhesive liquid, as is the case with gum arabic. To the latter class starch-gum likewise belongs. It is best characterised by its reaction with a solution of iodine, with which it acquires a reddish-violet colour, and by its optical properties with reference to a ray of polarised light, which it rotates towards the right; from which property it has received the name of Dextrin.

Sugar is a term likewise applied to a whole class of substances, which we shall describe hereafter. Starch-sugar is of the same nature as grape-sugar, which was known long before the theory of its production was understood. In unripe apples and pears it is well known that starch exists, as also that it disappears when at a later period grape-sugar is found in these fruits. Starch, in many instances, is thus shown to be the material from which nature prepares the sugar of fruits.

The conditions under which starch is converted into sugar are the following:

By spontaneous decomposition.—Ordinary paste, left to itself for two or three days, and prevented from drying up, becomes limpid, and at the same time somewhat sweet and strongly acid. Gum is produced, sugar, and afterwards lactic acid. When the starch contains gluten, or when flour is used instead of starch, more sugar is obtained, and the conversion proceeds much more rapidly; but the stinking odour of putrifying gluten is observed at the same time. Commercial starch is never quite free from gluten,

and consequently always stinks on becoming acid. Saussure obtained from 100 parts of starch, boiled to a paste with twelve times as much water, and allowed to undergo spontaneous decomposition for thirty-eight days, 47 parts of sugar and 23 of gum, when the operation was conducted in close vessels; and 50 parts of sugar and 19 of gum, when exposed to the air; the remainder was unchanged starch. The presence of air is consequently not absolutely necessary to this process, but it will be observed that, in the absence of air, the products weigh together as much as the starch originally employed, whilst, when the air has access, there is a loss of 15 per cent, probably occasioned by the fermentation of the sugar with the evolution of gas.

By boiling. — A long-continued process of boiling likewise converts starch-paste into gum and sugar. In Papin's digestor, at 160° (320° F.), with a pressure of about six atmospheres, almost the entire quantity of starch is converted into gum, with a very small quantity of sugar. At a temperature of 180° (356° F.), on the other hand, or in steam of nine atmospheres' pressure, nothing but sugar is obtained.

By acids.—Diluted acids have no action upon starch in the cold. If, however, weak acids are added to starch-paste, it soon becomes limpid, and is gradually converted by boiling, firstly, into dextrin, and then into sugar (Kirchhof). In the commencement, the liquid is deeply coloured blue by a solution of iodine; after a time, the colour becomes violet, and then purple (this is the period when the starch has become converted into gum); and, lastly, the colour entirely disappears, and the liquid then contains neither starch nor gum, but only sugar. Alcohol, which dissolves sugar, but not starch or gum, produces a coagulum as long as a trace of these substances remains in the liquid. If to 1 part of starch 4 parts of dilute sulphuric acid have been taken, the boiling must be continued for thirty-six or forty hours, the acid being the $\frac{1}{100}$th of the weight of the water; twenty hours are required when the acid amounts to $\frac{1}{40}$th; and only seven or eight hours when it composes $\frac{1}{10}$th of the weight of water.

There is no evolution of gas during this operation, nor is anything absorbed from the atmosphere; the same amount of acid is obtained in an unchanged condition, and it is immaterial whether open or close vessels are employed. The process is as independent of the peculiar properties of any single acid, for hydro-

chloric acid, phosphoric acid, tartaric acid, and oxalic acid, have precisely the same effect as sulphuric acid.

According to Saussure, 100 parts of starch afford 111 parts of sugar; according to Brunner, only 107 parts, as the mean of five comparative experiments.

By diastase.—It is very remarkable with what energy an infusion of freshly-germinated barley enacts the part of an acid in converting starch into sugar. This property is ascribed to the presence of a peculiar substance called *diastase*, of which we shall treat more fully in the chapter upon brewing.

By dry heat.—Simple heat has a more special action than any of the agents yet mentioned. When dry starch is gradually and uniformly heated in a vessel, without any addition of water, the moisture it naturally contains is expelled, and the starch may be heated to 160° (320° F.) without any other apparent change occurring. The granules retain their original spherical shape and appearance, but have become completely soluble in cold water; the starch has indeed been converted into gum, at a temperature between 140° and 160° (284°—320° F.); a little above which temperature empyreumatic decomposition ensues, and the starch becomes of a brown colour.

The examination of the specimens of gum obtained by different processes, has proved that, with reference to elementary composition, they are all alike, and correspond exactly with that of starch itself, whether prepared with the aid of acids, of hot water, or dry heat. The general conclusion therefore is, that whatever is stated of amidon, soluble or insoluble—of starch, starch-gum, dextrin, and leiokom, applies essentially to the same substance, only in different conditions of density, solubility, &c.

Production of starch-gum on a large scale.—It has been shown that, in a scientific point of view, starch-gum is closely allied to gum arabic; and this is still more the case with reference to its practical applications. The extensive use of gum arabic in the arts is mainly attributable to the properties which it shares with starch-gum of producing with water a sticky, mucilaginous, chemically indifferent, slightly coloured or colourless solution. Since the invention of the process for the production of gum from starch, and more particularly since the improvements introduced by the French, the expensive foreign gum is gradually giving place, in manufactories, to the cheaper starch-gum, the

fabrication of which is rapidly increasing; affording one of those interesting cases in which the intelligence and industry of Europe have been able to obtain, in an indirect manner, from their own resources, the produce which nature appeared to have solely accorded to the tropical regions. Not only is a portion of the tribute paid to foreign nations thus saved, but another market is opened to the agriculturist for the sale of his produce.

Starch-gum occurs in three different forms in commerce; sometimes in the shape of small transparent particles, in imitation of gum arabic; oftener as a thick syrup; but generally in the form of starch, more or less coloured.

Preparation by roasting.—At the commencement of the home production of gum, the starch was converted into gum by simple heat, or by roasting. This method, though simple, is not without its own peculiar difficulties. When all the starch is to be converted into gum, without leaving any portion unchanged or over-burned, all the grains must be heated to a temperature neither above or below 140°—160° (284°—320° F.) A slow, but gradual rise of temperature effects the object in view in the surest manner, as it is thus most easy to prevent over-heating; but the process is too tedious for the manufacturer. When the heat is applied more rapidly, there is great danger of over-heating the starch; and any degree above the temperature indicated gives rise to the production of empyreumatic products. This is the most common case in practice.

In ovens.—Starch is often roasted on the level surface of an oven, of the same construction as an ordinary baker's oven, over which it is spread out in thin layers. British gum is prepared in a similar manner, with several iron-plates, one above the other, upon each of which a layer of starch is strewn. In this manner, relatively, large quantities are made in a short time; but the temperature is regulated with difficulty, and the gum can only be obtained as a yellowish-grey, or dark-yellow flour. A safer method consists in spreading out the starch upon hurdles, in a kind of drying chamber, which is heated by the waste heat from another firing. This indirect heat renders the temperature more uniform, and easy of regulation.

In boilers over an oil-bath.—Boilers over an oil-bath are better calculated to afford a good product. These are constructed flat, and with a double bottom; the space between the two bottoms is filled with oil, which, with the aid of a thermometer, can be

regulated to a fixed temperature; and this constitutes the chief value of the apparatus. The starch is placed in the interior, upon the upper bottom, and is kept in constant agitation by a stirring apparatus, that each granule may come into contact with the metallic sides of the vessel, and thus become heated to the proper temperature. An excessive heat cannot possibly occur, under these circumstances. In order to hasten the process, however, the temperature must be raised higher than is absolutely necessary for the conversion of the starch into gum.

In cylinders.—The contrivance in most general use, is perhaps the *roasting cylinder*. This consists of a large drum or roller of tin-plate, placed in a special oven, and revolving on its axis at any required speed, resembling, in short, the common coffee-roaster. The revolution of the drum performs the same function as the rouser or stirring apparatus, in the foregoing plan, and effects the change of position of the individual grains much more effectually. Drums present the additional advantage that they can be speedily emptied, when the roasting process has attained the proper stage. In all these cases, the yellow or brownish colour produced by incipient decomposition is not to be avoided, and the tint of the starch is indeed the chief criterion by which the completion of the roasting process can be ascertained. On the other hand, it is well known that the colour is altogether foreign to the nature of the gum, and attributable to small quantities of empyreumatic matters, which can easily be removed by alcohol. This colour, however, is retained by the solution of the gum, and is transferred to all the objects treated with it; and so detrimental is it to the lighter colours in calico prints, that starch-gum cannot be used in those cases. For these reasons, improved processes were introduced; and one among these, now in general use, was patented by Henzé: it is founded upon the principle of aiding the action of a low temperature by that of acids, in such a manner that the original form of the starch is retained.

With nitric acid and heat.—Starch is moistened throughout its entire mass in cold water, in such a manner that it easily forms itself into balls, and to this water $\frac{1}{400}$th of the weight of the starch of nitric acid (sp. gr. 1.40) is previously added. The object of this moistening is to disseminate thoroughly the small quantity of acid through the comparatively large mass of starch. The moistened mass is first dried in the air in lumps, weighing about

25 lbs. each; the lumps are broken, after a short time, into smaller pieces, which are then dried in a drying chamber by a current of air. The temperature is gradually raised to 60° or 90° (140°—194° F.), when all the moisture is removed. The thoroughly dried lumps, which are not yet converted into gum, are finely ground and sifted, the meshes of the sieves being so small that only single starch granules can pass through. The starch is thus brought back to its original form, and is then again placed on the drying-stove upon hurdles, and the temperature raised to 100° or 120° (212°—248° F.) The change is effected in fifteen or five minutes, according to the temperature; the more nearly the temperature is retained at 100° C. (212° F.), the whiter the product. Leiokom, prepared in this manner, can only be distinguished from starch by its pale-yellow colour, and its complete solubility in cold water. The separate granules have not been altered in shape, as may be seen under the microscope.

Sulphuric and hydrochloric acids have been employed in place of nitric acid, but not with such signal success. Sulphuric acid renders the leiokom deliquescent, and consequently difficult of preservation. It is stated, by the Messrs. St. Etienne, in whose manufactory only hydrochloric acid is used, that the gum prepared by its agency is less liable to fall to pieces or crack than that made by the other methods. In this factory, the preparation of gum is finished by spreading it upon wire-gauze, through which a current of steam is passed. The product then forms itself into balls, which resemble gum arabic, without being loaded with any great excess of water; and this facilitates the subsequent drying.

Syrup of gum.—Some manufacturers have preferred producing a solution of gum at once, by treating starch-paste at the boiling temperature with acids (sulphuric acid) or diastase, they were induced to adopt this practice on account of the numerous applications for gum in the state of solution, as for the printing of silk, linen, cotton, wool, and paper; for water-colours, for stiffening and calendering cloths, for bandages in surgery, for glazing cards and paper, and in medicine. These solutions contain, in addition to unchanged starch, the agents which have been used in producing the gum. The sulphuric acid is easily removed by the addition of powdered limestone, which forms gypsum and from this the solution of gum can be decanted and evaporated to the proper consistence. The diastase, or infusion of malt, on the other

hand, cannot be removed, and remains in the commercial solution.

The manufacture of syrup is obviously more complicated than that of the leiokom itself; it is likewise very expensive to convey to a distance, from the large amount of water it contains, and is subject to one other serious objection, that of being mixed with more or less sugar, formed from the dextrin, and which, from the nature of the process, it is impossible to prevent. This admixture deprives the gum of its stability; the sugar, aided by the presence of particles of gluten, which accompany the starch, or still more by the ingredients of the infusion of malt, when that has been employed, passes into fermentation, which is accompanied by the odour of putrefaction.

The production of starch-gum by means of nitric acid, is, up to the present time, the best, more particularly as no sugar is formed in the process; and the entire quantity of the acid, with the exception of minute traces, can be expelled in the drying chambers.

It is worthy of observation, that a species of starch-gum, resembling in every respect the best quality obtained by means of nitric acid, or even whiter, is imported from France, and possesses a very distinct odour of malt. It is, therefore, probable that a method has there been discovered of producing starch-gum with infusion of malt, similar to that in which nitric acid is employed; but no further particulars are known respecting it.

When starch is treated with an excess of nitric acid (5 parts of acid of 1.42 sp. gr.), and heat is applied, an energetic oxidising process commences, and the starch becomes converted into oxalic acid. Indeed, all the oxalic acid of commerce is prepared in this manner.

Zyloidine.—When starch is acted on by nitric acid of a particular strength in the cold, the remarkable substance called zyloidine is produced; an account of which will be found in Vol. I, under the head of "Gun-cotton."

OF SUGAR.

Historical.—The practice of sweetening food is far more ancient than the knowledge of sugar. The Greeks and Romans, indeed the ancients in general, employed honey to render their food palateable. At a later period, a particular kind of honey became known,

mel arundinaceum, which exuded from a species of cane (very probably the sugar-cane). Dioscorides, in the first century, very distinctly states that a kind of honey was found on canes which grew in India and Arabia Felix, and was called σακχαρον, or sugar. Pliny states the fact in almost precisely the same words, with the remark, that the sugar was only employed in medicine. Sugar, in common with many of our modern articles of luxury, came first through the apothecaries' hands to be an essential requisite of our daily food.

The use of sugar as an aliment remained long unknown in Europe, and appears to have been only first introduced, at least into the northern parts, at the time of the Crusades. The cultivation of the sugar-cane was introduced into Cyprus from Asia, where, about the year 1148, a considerable quantity was grown; at the same time it was transplanted to Madeira, and from thence, in the year 1506, to the West Indies. The culture of the sugar-cane existed on the coasts of Andalusia prior to the invasion of the Arabs, amongst whom many sugar manufactories existed. From that period — the middle of the fifteenth century — the art of boiling down the juice of the sugar-cane for the production of sugar, takes its rise. The art of refining the crude product is of much later origin, and was the invention of a Venetian. In the year 1597, a sugar-house (refinery) existed in Dresden. The use of lime-water and albumen, for refining sugar, is described by Angelus Sala, in the beginning of the sixteenth century, in his "Saccharologia." The name *Candy* is even mentioned in the "Alchemia" of Libavius (1595). Up to the close of the seventeenth century, sugar was too dear in Germany to be used by the poorer classes, who substituted syrup and honey for refined sugar. With the progress of civilization, the use of cane-sugar has gradually reached the lowest classes of society, and the consumption has consequently increased to a very great extent. The use of tea and coffee has been chiefly instrumental to its general introduction.

After sugar had been imported into Northern Europe for several centuries, and was there purified or refined, a change was brought about, in the year 1747, by the discovery of a German chemist, Marggraf, that cane-sugar existed in the ready-formed state, in different roots, particularly in the beet-root. Forty-nine years after that discovery, the first beet-root sugar factory was established by Achard, at Cumoom, in Silesia, as an experiment, without any great amount of success.

The art of separating sugar from the juice of the beet-root, as well as the artificial production of sugar from starch, both owe their practical accomplishment to the blockade of the continent, which answered as a protective system, and led to their present state of prosperity.

The idea connected, in ordinary life, with the generic term sugar, is somewhat in contradiction to the scientific definitions. The chemists demand that any kind of sugar should be not only sweet and soluble, but should likewise be capable of undergoing *fermentation*. This property is in reality, however, peculiar to grape-sugar, which, under the action of ferments, is broken up into carbonic acid and alcohol. The other varieties of sugar—cane-sugar and milk-sugar—are first converted by the same agents into grape-sugar, and then undergo fermentation in an indirect manner. The want of the fermentative property characterises *mannite* or *manna-sugar*, which was wont to be classed among the sugars, and is a saccharine matter, constituting the chief ingredient of the manna employed in pharmacy. It occurs in the juice of some kinds of ash, in orchard trees, the root of celery, and is the product of a special mode of decomposition (manna-fermentation), to which the other kinds of sugar are subject.

This line of demarcation is not arbitrary, for the property of undergoing fermentative decomposition is deeply rooted in the chemical nature of the bodies possessing it, and is reflected in an interesting manner by their composition.

Relations of the varieties of sugar to each other.—Crystallized grape-sugar is composed according to the formula $C_{12} H_{14} O_{14}$. At a temperature of 100° (212° F.), or somewhat under it, this sugar melts and begins to evolve aqueous vapour. The loss of water amounts to 9 per cent, or 2 equivalents. In its combinations with other bodies, one, and under some circumstances, two additional equivalents are separated. Crystallized grape-sugar contains, therefore, at least 4 equivalents of water as such $= C_{12} H_{10} O_{10} + 4$ Aq, and that which has been dried at 100° (212° F.) 2 equivalents $= C_{12} H_{10} O_{10} + 2$ Aq.

Crystallized cane-sugar is constituted according to the formula $C_{12} H_{11} O_{11}$. It melts unchanged at a temperature of 180° (356° F.), at 210° to 220° (410°—428° F.) it is changed with the evolution of aqueous vapour into a brown mass, which is not sweet or fermentible, and is called Caramel. Cane-sugar loses in this case 2 equivalents of water; these 2 equivalents are either partly or

entirely separated when sugar enters into combination with bases. Its real composition is therefore $C_{12} H_9 O_9 + 2$ Aq. It is also an important remark, that caramel is obtained when the water is entirely expelled from grape-sugar.

This is no longer the case with *milk-sugar*, the composition of which corresponds to $C_{12} H_{12} O_{12}$; it parts with water at 140° (284° F.), when gradually heated with 2 equivalents, and by a slow application of heat with $2\frac{1}{2}$ equivalents, so that it must be viewed as composed of $C_{12} H_{12} O_{12} + 2\frac{1}{2}$ Aq $= C_{24} H_{19} O_{19} + 5$ Aq. All these varieties of sugar, therefore, only differ in the quantities of hydrogen and oxygen which they contain, and these in the relative proportions in which they unite to form water. This will be obvious from the following tabular summary:

Formulæ.	Composition in 100 parts:			
	Carbon.	Hydrogen	Oxygen.	
$C_{12} H_9 O_9$ . . .	47.05	5.88	47.05	Caramel (also cane-sugar in many of its compounds.)
$C_{12} H_9 O_9 +$ Aq .	—	—	—	(Grape-sugar in many combinations.)
$C_{12} H_9 O_9 + 2$ Aq	42.10	6.43	51.56	Crystallized cane-sugar; milk-sugar slowly dried.
$C_{12} H_9 O_9 + 3$ Aq	40.00	6.66	53.33	Grape-sugar dried at 100° (212° F.); crystallized milk-sugar.
$C_{12} H_9 O_9 + 5$ Aq	36.36	7.07	56.56	Crystallized grape-sugar.

The addition of 1 equivalent of water is therefore all that is required, to convert crystallized cane-sugar into dry grape-sugar; while the converse of this operation can never be accomplished, cane- and milk-sugar under the circumstances named, are converted into grape-sugar, but no attempts have yet been successful in converting grape-sugar into cane- or milk-sugar.

Cane-sugar is found in the juice of the stems of the maple, birch, palm and nut trees, and in the stalks of Indian corn and in the sugar-cane. Crystals of chemically pure cane-sugar have been observed exuding from the axillary cavity of the *Clerodendron fragrans*. The beetroot and many other tubers, which are not genuine roots, but perform the function of stems, likewise contain cane-sugar. In tropical climates the sugar of most fruits is said to be cane-sugar. If true, this is an exception to the rule, as in the temperate zone the sweet principle of nearly all fruits is grape-sugar.

Grape-sugar is nearly always accompanied in fruits by an acid —malic, citric or tartaric acid. This different modes of occurrence leads naturally to the conclusion that cane-sugar is a primitive formation, or is formed in the first elaboration of the food of plants, while grape-sugar is of secondary origin, or a product of the more advanced chemical activity of the vegetative process. The nourishment taken up by plants is subject to a more extensive elaboration when it is to be converted into grape- than when into cane-sugar. All the artificial processes for the production of sugar afford grape-sugar—for instance, the production of sugar from starch, woody fibre, &c.; while cane-sugar cannot be obtained artificially by any known method. The crystalline portion of honey is also grape-sugar.

The transformations to which sugar is subject when exposed to heat and reagents are of the utmost importance to the processes employed in its manufacture where they come into active operation. When a solution of cane-sugar in water is kept for a long time—for instance, during a whole day—at the boiling temperature, it is converted partly into grape-sugar and partly into uncrystallizable sugar.

Chemical action of foreign substances upon sugar. Action of acids.—All the acids, sulphuric, hydrochloric, nitric, oxalic, tartaric, acetic acids, &c., convert a solution of cane-sugar into grape-sugar, even in the cold; the conversion is rapid when the amount of acid is considerable and slow in the opposite case; thus 300 parts of sugar dissolved in three times their weight of water become grape-sugar in thirty-five hours when mixed with 1 part of sulphuric acid; the same effect is produced in two hours when the acid amounts to 44 parts. If an acidified solution of sugar is allowed to boil for some time the decomposition extends further; the colour becomes deeper, and a dark-brown substance in brilliant scales is deposited, or floats on the surface of the liquid as a scum. When the air has access, and then only, a little formic acid is produced. During the whole process the acids remain unaltered, and a large quantity of the sugar is converted into the uncrystallizable modification. The brown substance is composed of an acid and an indifferent body, both of which have much resemblance with the products of the decay of wood, ulmin and ulmic acid, and are hence called sachulmin and sachulmic acid. Whether the two bodies are identical, as some have maintained, must remain undecided at present. Unfortunately the other

point, which is of much greater practical importance, the loss of the property of crystallizing to which cane-sugar is subject under these circumstances, has by no means been clearly explained by scientific research. This much, however, is certain, that the uncrystallizable sugar is fermentable, possesses a sweeter taste, and is more soluble in alcohol than the crystallizable sugar, and can only be obtained in the solid form by evaporation to dryness. It is then in the form of a brown amorphous substance, which attracts moisture, and runs into syrup again when exposed to the air. Uncrystallizable sugar is the principal ingredient in the treacle or molasses of the shops, and in consequence of its viscid character, is distinguished by some as a peculiar modification under the appellation *mucilaginous sugar*. Others, again, consider molasses to be a combination of the acids (concerned in the transformation of cane-sugar) with the product of the reaction or with grape-sugar. The truth is, that an accurate knowledge of the nature of molasses is still wanting.

Action of bases.—The uncombined bases, potash, soda, lime, baryta, oxide of lead, &c., enter into combination with sugar, without producing any colour, yielding a series of compounds which have little or no sweet taste. The combination of lime with sugar is insoluble in hot, but soluble in cold water. If a solution of sugar is boiled with an addition of caustic potash or lime, similar products are formed as when acids were employed; grape-sugar is obtained, and at a later period two additional products, melasinic and glucinic acids. The former dissolves with a deep-brown colour in the liquid. Cane- and grape-sugar combine with salts—for instance, with common salt—and give rise to bodies exhibiting a mixed or not at all sweet taste.

The objects of technical interest are confined to the manufacture of grape-sugar from starch, and the separation of cane-sugar from the juices of the sugar-cane and beet-root.

OF STARCH-SUGAR.

Practical value of starch-sugar.—The discovery of the method of converting starch into sugar did not remain long, as was to be expected, without application. The manufacture of starch-sugar is indeed a branch of considerable industrial importance, the extent of which, and the interest attached to it, are however very restricted,

as the grape-sugar always obtained by this process is much less applicable to most of the purposes for which sugar is required. The latter kind of sugar is only capable of being substituted for cane-sugar in a very limited number of cases, and will by no means supply its place for sweetening tea, coffee, or other alimentary substances.

For these purposes it is, however, that the large amount of sugar consumed is employed. The causes for this arise from the greater difficulty of crystallizing grape-sugar, which is a guarantee to the public of its purity, and its lesser sweetening power and degree of solubility. Both kinds of sugar are soluble, in all proportions, in boiling water; but, under similar circumstances, 100 parts of grape-sugar require 133 parts, or, according to others, 163 parts of cold water; while 100 parts of cane-sugar only require 33 parts to be completely dissolved. In both cases, whether the water is hot or cold, the solution of the grape-sugar takes place more slowly; and in order to produce an equal sweetening effect, two and a half times as much grape as cane-sugar is required. Powdered grape-sugar has a flowery taste when placed upon the tongue, and very gradually becomes sweet as it dissolves, having a mucilaginous taste at the same time. Cane-sugar gives a purely sweet taste, in a much greater degree, and in a direct manner. In order to render the two kinds upon an equality, in an economical point of view, 5 lbs. of grape-sugar should only cost as much as 2 lbs. of cane-sugar.

Principles of production.—The conversion of starch into sugar may be effected in a variety of ways, which have all been indicated at (pp. 236 and 237.) On the manufacturing scale, inasmuch at least as the production of sugar is the ultimate object, practice has confined itself to the use of sulphuric acid, because it is cheaper, and after having effected its object is easily removed in a short time. As all the varieties of starch are equally adapted for the production of sugar, the cheapest, or potato-starch, is only employed.

When the most extensive scale of manufacture is not carried on, the operation is conducted over an open fire, in a deep leaden pan, the under part of which is covered with iron in such a manner that the flame can never reach the lead. In larger manufactories, steam heat is employed with greater advantage, and is applied in precisely the same manner as in the stearine factories; only the tins or pans used need not necessarily be constructed of lead, as

much weaker acid is used. A steam-pipe conveys a jet of steam into each pan, which communicates directly with the liquid to be heated.

Actual operation.—The time required for the conversion of starch into sugar is in a very great degree dependent upon circumstances. It is accelerated by an elevated temperature, and by an increased quantity of sulphuric acid, from a duration of twelve or more hours to two, or even less, with an equal quantity of materials. The danger of decomposing, changing, and destroying the sugar, is then however augmented in an equal degree. With reference to temperature, the boiling-point of the liquid, ranging from 100° to 104° (212°—219.5° F.) is found very suitable; and, as regards the proportion of sulphuric acid and water, Kirchhoff has shown, that for the conversion of 100 parts of starch into sugar, by means of 200 parts of water and ½ sulphuric acid, several days are necessary; while with 600 parts of water and 10 of sulphuric acid, seven or eight hours are sufficient.

Many employ for 100 parts of starch 1 to 1½ parts; others, with better success, 2 to 2½ parts of English sulphuric acid: the necessary quantity of water varies from 300 to 400 parts.

When the starch and sugar manufacture are carried on together, it is unnecessary to dry the starch. It can be used as it is deposited from suspension, the water which adheres to it being taken into account. It is hardly necessary to add, that the acid is allowed to flow in a small stream into the water, and not the water into the acid. Originally, the entire quantity of starch to be used in one operation was introduced at once into the acidified water; in this manner, before any further action can ensue, a great quantity of a thick paste is produced, which is difficult and inconvenient to manage. A still greater disadvantage attending this injudicious method is, that the sulphuric acid is compelled to attack at once the whole mass of starch. Now the action of a substance is less energetic and more slow in proportion as the bulk of the body upon which it has to act is increased; when, therefore, the remark made at p. 235 is borne in mind, that the sulphuric acid employed in transforming starch into sugar is neither decomposed, nor enters into any new compound, but remains unchanged, it will be perfectly clear that the manufacturer who adds the starch gradually in small consecutive quantities has a great advantage in the saving of time, for the acid in these

cases has only to exert its action upon each successive portion of starch, and that action being completed, it is then in a condition to exert its full action upon the next, and so on. It is equally useless to convert the starch previously into paste by boiling; indeed, the viscidity of the paste is positively hurtful. Some are in the habit of adding the starch by a spoonful at a time, but the most advantageous plan is the following:

The acid is diluted with the greater portion of the water or about two-thirds, and the mixture is brought to the boiling-point in the pan, or in the vat when steam is used. In the meantime, the other third of the water has been stirred with the entire mass of the starch to a thin milky liquid, which is placed in a reservoir above the pan, and warmed to a temperature of 50° (122° F.): at a lower temperature it would cool the acid too much, and at a higher, the starch would become paste, both of which are objectionable. The reservoir is furnished with a pipe and cock, so that the starch can be allowed to flow in a thin, uninterrupted stream into the pan or vat containing the acid. The latter, during the time the starch is flowing into it, must be kept in constant motion by means of a rouser, or by steam. The quantity of starch is suited to the capacity of the pan or vat. The conversion, upon this plan, is so rapid, that the starch becomes almost instantly limpid, and hardly acquires the consistence of paste; it can consequently be allowed to flow down so quickly, that 100 lbs. of starch are introduced in two hours and a half. The boiling, which must be uninterrupted during this time, is continued a quarter or half an hour after the entire mass of starch is in the pan, in order to convert the last portions into sugar. This point may be accurately recognised by the clear and limpid consistence of the liquid. It should no longer be turned blue by iodine (*i. e.* should be free from starch), and should afford a very insignificant or no precipitate (starch or starch-gum), with an excess of alcohol. The sulphuric acid may then be separated. The fluid is now allowed to cool, by shutting off the steam or damping the fire, and drawn off into a precipitating trough.

While a fresh charge is introduced into the pan, the saccharine liquid is treated with pulverized chalk (or powdered limestone, which settles down more rapidly), as long as effervescence ensues, or blue litmus paper is reddened. If the whole of the chalk were introduced at once, the liquid would overflow. Rather more chalk will be required than the quantity of sulphuric acid employed.

In this operation the sulphuric acid combines with the lime, and forms the difficultly-soluble sulphate of lime or gypsum, which for the greater part settles down, while the carbonic acid of the chalk is expelled.

Burnt lime would not only be more expensive, but any excess of it would combine chemically with the sugar, which is not the case with chalk or limestone.

The liquid drawn off from the gypsum, an operation which occupies half an hour, contains gypsum in solution and other substances produced from the sugar, which colour it brown. It is first evaporated, until it attains a specific gravity of 1.28, and then allowed to stand, that the gypsum separated by the evaporation may subside; the syrup is then drawn off. This syrup is itself saleable for many purposes, when colour is not an object; for others, however, it must be further purified and discolourized. The best apparatus for this purpose is Dumont's filter, used also in the refineries of cane-sugar; and most of the other contrivances employed in the purification of starch-sugar are borrowed from the same source, and will be minutely described hereafter. Some manufacturers are in the habit of adding ground animal charcoal to the syrup, which is then strained through an ordinary cloth-filter.

Form of the commercial sugar.—The discolourized and clarified syrup may, according to circumstances, be brought into commerce in three different forms: as syrup; as a granular, moist mass, like crystallized honey; and, lastly, as solid dry sugar. In the first case, the liquid must be rapidly concentrated to the consistence of 30° B.=1.24 specific gravity; in the second, when it has to be conveyed to a distance, it is evaporated to the specific gravity of 1.44, or 50° B., and exposed in flat vessels to crystallize. The slight tendency of the sugar to assume the crystalline form causes the mass to solidify in imperfect warty concretions, which gradually spread through the liquid, and as they increase, inclose a considerable quantity of the liquid portion; so that the whole forms a sticky, granular, moist mass, which is packed at once in casks.

The production of dry sugar, first introduced by Fouchard, is much more tedious and circuitous. The first operations are the same: the liquid is discolourized, clarified, and evaporated to 30° B., and set aside to deposit the gypsum. As soon as the liquid has cooled to about 22° C. (72° F.) it is drawn off into casks —white wine casks are the best—which have a double bottom, the

two bottoms being a few inches apart. The upper bottom is pierced with a number of apertures, which, in the first instance, are plugged up. In from eight to fourteen days, crystallization commences; and when this has spread through the entire mass, and the surface alone is liquid, the plugs are removed, and the syrup allowed to flow away. When nothing more flows off, the granular mass must be dried. If this were effected without artificial heat, the process would require too much time; and if the heat were applied in an ordinary drying chamber, a portion of the crystals would be again dissolved, and all would be moist. This difficulty has been overcome by Fouchard, in a simple and ingenious manner. The beds of his drying ovens are composed of thick slabs of gypsum, which absorb the greater part of the syrup, and thus admit of the grains of sugar being dried at a comparatively low temperature. The dry mass is passed through sieves, the lumps crushed and sifted, and the powder packed in dry casks. This form is preferable to that of syrup, and has many advantages over the moist sugar, which forms very hard and firm, although moist masses.

The filter, the deposits of gypsum and the vessels, are always well washed, and the wash-water employed for a subsequent operation.

During the whole process, and more particularly during the conversion of starch into sugar, a most nauseous, unpleasant smell is evolved, which is commonly ascribed to the action of the acid upon the minute quantities of oil contained in potato-starch. This odour renders the starch-sugar-houses a nuisance to their neighbours; it can, however, be rendered innocuous by carrying the vapours through a fire.

It has been already stated, that starch-sugar is not calculated thoroughly to replace cane-sugar. The admixture of very white crystalline starch-sugar, prepared according to Fouchard's or some similar process, with some sugar sold in the form of powder, as is frequently done in France, is a true adulteration, for the starch-sugar has a very much less sweetening power than that of the cane.

Applications.—Starch-sugar is chiefly employed for the manufacture of alcohol and vinegar, to improve the quality of inferior wines, &c. The French, who know as little about the quality of beer as they know of the practical principles of brewing, are likewise in the habit, some districts excepted, of adding considerable

quantities of starch-sugar to their wort. Many breweries are connected, for this reason, with factories for the production of starch and sugar. However correct this practice may be in an economical and theoretical point of view, yet every consumer of beer has an indisputable right to reject it on the grounds of being prejudicial to the flavour of the beer. Starch-sugar (syrup) has not only a somewhat bitter after-taste, but is always associated with gypsum, and sometimes, when carelessly prepared, with sulphuric acid, both of which substances are very much calculated to deteriorate the quality of the beverage. Many French brewers prefer converting the starch into sugar by means of an infusion of malt; but as the constituents of the infusion of malt can only be subsequently separated with much difficulty, and imperfectly—which is not the case with the acid—the latter must always be employed when pure sugar is required.

The properties of starch-sugar afford so ready a means for falsifications and fraud, that in France it has been specially and most extensively manufactured for those purposes. At present there is an annual demand for more than 100,000 cwts. Starch-sugar, in the granular crystallized form, has there been passed off as an inferior kind of Bretagne honey, and even sold for medical use to replace the second, brown, soft kind of manna.

OF CANE-SUGAR.

The great mass of cane-sugar is obtained from the sugar-cane and from beet-root, a lesser quantity (in America) from the juice of the maple-tree.

1. *From the Sugar-cane.*

The sugar-cane, *Saccharum officinarum*, is a perennial plant, belonging to the family of the grasses, of which several sub-species are cultivated. The cane resembles a gigantic reed, which throws up stems 1 to 2 inches in thickness, and 120, 160, and even 200 inches in height, intersected with numerous knots, and bearing a bunch of flower at the apex. Each cane or stem is covered externally with a very hard silicious integument which encloses a woody but porous net-work, a kind of pith, in the cells of which the saccharine juice is contained. Three species are chiefly distinguished:

The *Creole cane*, with dark-green leaves and thin, very knotty

stem, is indigenous to India, and has been transplanted from thence into Sicily, the Canary Islands, the Antilles and into South America.

The *Batavian* or *striped cane,* with a dense foliage covered with purple stripes, originated in Java, where it is chiefly used for the manufacture of rum, and lastly:

The *Otaheite cane,* which grows the most luxuriantly, is the most juicy, and yields the largest produce from the same extent of soil. This variety soon became spread over the West Indies and South America.

The sugar-cane, originally a bog-plant, demands a hot (tropical or sub-tropical) climate, and a very nutritious, though at the same time, moist soil. It is propagated by slips (pieces of the stem, with buds upon them, and about 2 feet long), which according to the temperature of the neighbourhood, require twelve or sixteen months to come to maturity. In Andalusia the sugar-cane is said to be fit to cut in nine months. Towards the flowering season the leaves fall off, beginning with the lowest, and the stem acquires a straw-yellow colour. Many planters cut the cane before the flowering season, but the greater number cut it several weeks after. In the (tropical) plantations it is so arranged that the divisions of the sugar-fields ripen one after the other, and not all at the same time, which gives more regularity to the operations. The sugar-cane will bear a large quantity of manure; this must abound in nitrogen, but contain as small a quantity of saline matter as possible. After the harvest, the roots, which are left in the ground after cutting the cane, strike again and again. After five or six years, however, they are entirely renewed.

In the first two varieties, the surface of the stem and the basis of the leaf are covered with a white, or often sea-green dust, which is a kind of vegetable wax, *cerosin,* soluble in alcohol. In the creole cane there is only a ring of this dust at every knot, as is the case with many other plants. The wax melts at 80° (176° F.), may be burnt in the form of a candle, is easily crystallized, and consists of 81.4 carbon, 14.1 hydrogen, and 4.5 oxygen, (Avequin, Dumas.)

As might naturally be expected, the amount of sugar and other constituents in the sugar-cane varies with the variety, the mode of culture and the climate; in general, however, a juice is obtained by pressure, which is nearly a pure solution of sugar in water, with mere traces of saline matter, albumen and colouring matters. The

residue after pressure consists of the cane-straw, called *bagasse*, or trash. There have been found:

	In the Otaheite cane: from Martinique, (Peligot.) 1.	from Guadaloupe, (Dupuy.) 2.	In the creole cane: from Cuba, Casaseca. 3.
Water	72.1	72.0	65.9
Sugar	18.0	17.8	17.7
Woody matter	9.9	9.8	16.4
Salts	—	0.4	—

100 parts of perfectly dry sugar-cane consist, therefore, according to the analyses:

1. and 2. of 35 woody fibre, and 65 soluble matter,
3. of 48 „ „ and 54 „ „

Peligot investigated in the Otaheite cane, whether important differences in the quantity of sugar could be detected in the different sprouts after the first, second and third harvest, or in the different parts of the same cane, the knots, &c.; he found that, under all circumstances, the cane consisted of 72 to 74 parts of water, 15½ to 18 parts of soluble matter, and 8 to 11 parts of woody fibre, and consequently exhibited no very great discrepancies; the knots, on the other hand, consisted of 71 water, 12 soluble matter, and 17 woody fibre.

A more extensive investigation of the sugar-cane of Guadaloupe, and of the straw obtained from it, has been furnished by Hervy; he examined two specimens, the one (I.) from a dry, calcareous, elevated soil; the other (II.) from a low soil in the neighbourhood of volcanic eruptions. Both specimens were cut into slices and dried.

Constituents.	No. I.		No. II.		
	Sugar-cane.	Bagasse, or straw.	Sugar-cane.	Bagasse, or cane-straw.	The same, brown, and decomposed.
Sugar	64.6	22.5	67.00	29.2	42.4
Extractive matters	0.3	—	0.3	—	—
Wax	0.9	1.8	1.2	1.6	1.6
Soluble salts	0.3	1.8	1.2	2.4	3.3
Insoluble salts	1.00		1.3		
Woody matter	32.6	73.90	28.9	66.8	52.8
	99.7	100.0	99.9	100.0	100.1

From this comparison, it is first obvious that the relation between the juice and the woody matter of the sugar-cane is not uniform. On the other hand, it proves that in the juice of the cane there is, besides sugar, only a very small quantity of other ingredients. Amongst these, the different salts, particularly the soluble salts, are most injurious to the sugar during the process of manufacture, and a juice containing the least quantity of salt is decidedly preferable upon that account.

The nature of these salts has been lately investigated by Stenhouse in his experiments upon the mineral constituents of the sugar-cane. He found, after deducting carbonic acid:

	In the sugar-cane from Trinidad, in 100 parts of ash.				In the sugar-cane of Berbice, in 100 parts of ash.		
	No. 1.	No. 2.	No. 3.	No. 4.	No. 1.	No. 2.	No. 3.
Silica	45.78	42.81	45.50	40.85	46.24	49.74	44.68
Phosphoric acid	3.75	7.97	8.16	4.53	8.12	6.53	4.84
Sulphuric acid	6.64	10.92	4.56	10.80	7.48	6.37	7.67
Chlorine	2.70	1.02	8.85	5.47	2.39	2.36	4.34
Lime	9.13	13.17	8.73	8.96	5.75	5.07	4.45
Magnesia	3.65	9.86	4.41	6.84	15.53	12.94	11.78
Potash	27.32	11.99	15.00	21.39	11.87	13.62	16.81
Soda	1.03	2.26	4.79	1.16	2.62	3.37	5.43

With reference to the sugar, it has been decidedly proved by scientific investigation that the whole of it contained in the cane or fresh juice, is crystallizable cane-sugar. It is, therefore, the more remarkable, that by the present process of boiling of the 18 or 20 per cent of crystallizable cane-sugar, which is contained in the sugar-cane, not more than $7\frac{1}{2}$, or between 6 and 10 per cent, is actually obtained—or not quite one half. Two causes are principally active in producing this enormous loss; first, the defective method of expressing the juice; second, the chemical changeability of the sugar, which, during the course of boiling, has abundant opportunity of showing itself, giving rise to the production of the well-known secondary product, molasses (mucilaginous or uncrystallizable sugar).

PRODUCTION OF SUGAR FROM THE SUGAR-CANE.

General prefatory remarks.—The facts already noticed prove that the juice of the sugar-cane is purer, and contains twice as much sugar as that of the beet-root. Other circumstances being equal, the production of sugar from the sugar-cane would

be far more profitable than from beet-root; but in reality the circumstances of production are very unequal. The sugar-cane contains twice or three times as much woody fibre as the beet. This substance, in the case of the latter, is soft and full of cells; in the sugar-cane, it is fibrous and spongy, surrounded by a hard integument, and consequently more difficult to submit to pressure. In the regions in which the sugar-cane thrives, the temperature of the air is higher, and favours the fermentative processes, particularly the mucic-fermentation, in the highest degree; the danger of decomposition occurring in the sugar of the juice is therefore very much greater than in the beet-root.

Lastly, the districts where the sugar-cane is cultivated are in general deprived of the advantages of machinery and science, the production of sugar in the colonies is consequently placed in hands which are much less to be trusted—and the whole process is very imperfectly conducted, as compared with the production of sugar from the beet.

It will be easily understood, after these explanations, that the actual state of the colonies, possessing great advantages in the raw material, is nevertheless very unfavourable to a good method of production; and that the division of labour between the colonies and the mother countries, which is of such long standing, is not continued without sound reasons. The main object of the sugar-boilers in the colonies is to convert the sugar contained in the cane as speedily, and with as few operations as possible, into a transportable commodity—into raw sugar. A larger produce as the result of more careful manipulation, and the greater stability of the sugar, during the transport, were consequently objects which, till within the last twenty years, were very little attended to, and immense quantities of sugar were annually destroyed in consequence of this neglect.

The production of white loaf-sugar from the raw material was left to the refiners with their more perfect machinery in Europe. The production of sugar from the cane is still carried on upon the same principles; but a commencement has been made to bring the interests of the refiner more into unison with those of the colonial planters, and to apply the numerous improvements, and great experience obtained in the beetroot sugar manufactories to the cane production. This transference will probably only become profitable when the culture of the cane is disconnected from the manufacture of sugar.

In the East Indies, the native place of the sugar-cane, a division

of labour in the production of sugar has long existed, the two branches of industry being carried out by different castes: the *Ayots*, very poor peasants, dependent upon the land owners, cultivate the cane, express the juice, and when evaporated to the consistence of syrup hand it over to the *Goldars*, who produce the solid sugar. The individual farmers hire the simple and crude vessels from more wealthy possessors; but the conversion of the juice of the cane into *goor* or *juggery* (the name given to crude syrup) is undertaken by a number of farmers, who confine themselves to that branch, and the process is carried out in common by association, the produce from each man's land being sent to the common manufactory, a plan which has been proposed by Griesheim as suitable to the West Indies.

From these prefatory remarks we pass to the description of the ordinary process of manufacture.

A. PRODUCTION OF RAW SUGAR.

a. Expression of the juice.

Presses.—One source of the loss of sugar consists in the canes being brought to the press before they are fully ripe, and not being crushed immediately, the juice is partly injured before it is worked. It is consequently a most important rule not to allow the cut canes to lie, but to crush them as they are brought from the field, and to allow no time for fermentation by boiling down the juice immediately.*

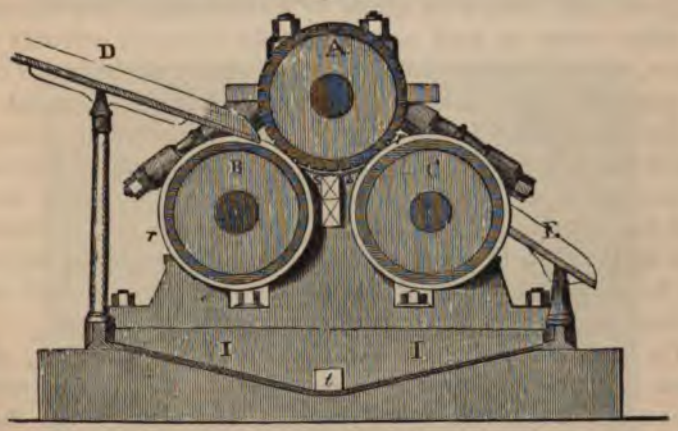
The original crushing apparatus of the Indians, consisted of a kind of squeezing mortar worked by a yoke of oxen. The mortar is constructed from a piece of the trunk of a tree (tamarind) hollowed out, and furnished with an aperture for drawing off the juice, its lower part being firmly fixed in the earth. The pestle or stamper of the mortar is a strong beam 18 feet long, and rounded at the bottom, which exerts a squeezing or crushing action. It is placed in an inclined position in the hollow part of the mortar, forming a double-armed lever, the fulcrum of which is situated at the edge of the mortar. The power of the animals is applied at the long upper end, the lower one being thus pressed with great force against the opposite side of the mortar. The animals, and

* Mitchell proposes to obviate this necessity by steeping the recently-cut cane in boiling hot water, so as to coagulate the albumen and thus altogether prevent any fermentation.

with them the pestle, moving in a circular direction, all the pieces of cane thrown into the mortar are crushed between the sides of the mortar and the pestle. Sometimes the pestle is shortened, and its upper end converted into the point of attachment of an upright two-armed lever to which the animals are yoked. Squeezing mills, with upright stones, like those employed for crushing oil seeds, were also used. Lastly, amongst the ancient Indian instruments, some presses, with upright rollers have been discovered at Chica Ballapura, and some with horizontal rollers, at Burdwan, near Calcutta, which in modern times have superseded every other kind of press in the West Indies.

The presses of the former kind, introduced by Gonzales de Velosa, which are still used in many places, consist of three stone or iron upright rollers. The horizontal rollers are, however, more economical (Fig. 63), and have the advantage of allowing the

FIG. 63.



canes to be delivered between the rollers in a more easy and regular manner. The rollers *A, B, C,* Fig. 63 (of 0.6 meter= 24 inches external diameter) are constructed of cast iron with projecting rims *r r,* in order to prevent the canes from passing over the sides. To the axle of each roller a toothed wheel is attached, which works in that of the next, so that the motion is not communicated by simple friction. The canes are introduced from the inclined plane *D* between the rollers *A* and *B,* the grooving on the roller *A* is necessary to enable the roller to carry the cane with it. The crushed cane is guided by the plates *s s* to the other side between the rollers *A* and *C,* where the fully

expressed cane falls over into the channel *E*. The juice collects in *II*, and flows away through *t*. The presses only work well when the cane is crushed between the first pair, and the juice is expressed between the second pair of rollers, and the expressed spongy cane is not allowed to come again in contact with the juice to reabsorb it. The objects are better carried out when *B* is grooved instead of *A*, and the distance between the smooth rollers *A* and *C* is narrower than that between *A* and *B*, or indeed is so narrow as barely to admit the cane to pass. The proper degree of velocity for the rollers is $3\frac{1}{2}$ feet per second at the periphery.

Various improvements in the machinery for expressing the juice of the cane have been very recently proposed, amongst which the following are the most important:

The first that we shall notice are the mills constructed for the colonies, by Messrs. Pontifex and Wood, of London.

These mills should be driven by a steam-engine in preference to either water or wind power, in order to ensure certainty of action, unless a plentiful and constant supply of the former can be procured. The boilers should not be more than from 20 to 25 feet long, and 6 feet in diameter, for convenience of carriage, and the more simple they are in construction the better. The best form of boiler is, if coal is to be used as the fuel, a circular body with flat ends, the fireplace being in the single flue tube. If trash is to be the fuel, the fireplace should be underneath the boilers, the flue running to the back of the boilers, returning through two or more tubes, and finally out of the side flues.

The mills are constructed with three horizontal rollers, the space between the top roller and that of the bottom ones, against which the canes first impinge, is somewhat less than $\frac{1}{4}$ of an inch, whilst that between the top roller and the second of the bottom ones should only be sufficient to admit of a piece of paper being passed between them; but this is a point which must be left to the practical experience of the planter, as so much depends upon the quality of the cane, the thickness of its rind, &c.

Fig. 64 shows an elevation of the three-roller horizontal cane mill, with its foundations, and the mode of fastening it down. Motion is given to the top roller by means of the large cog-wheel at the back of the mill, which in turn communicates motion to the two bottom rollers by means of small

FIG. 64.

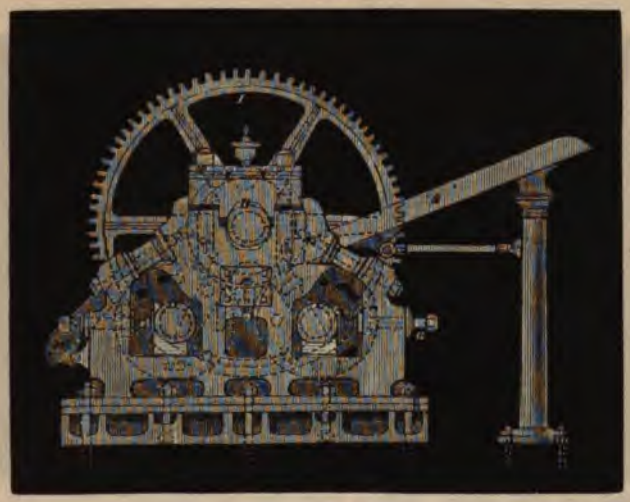
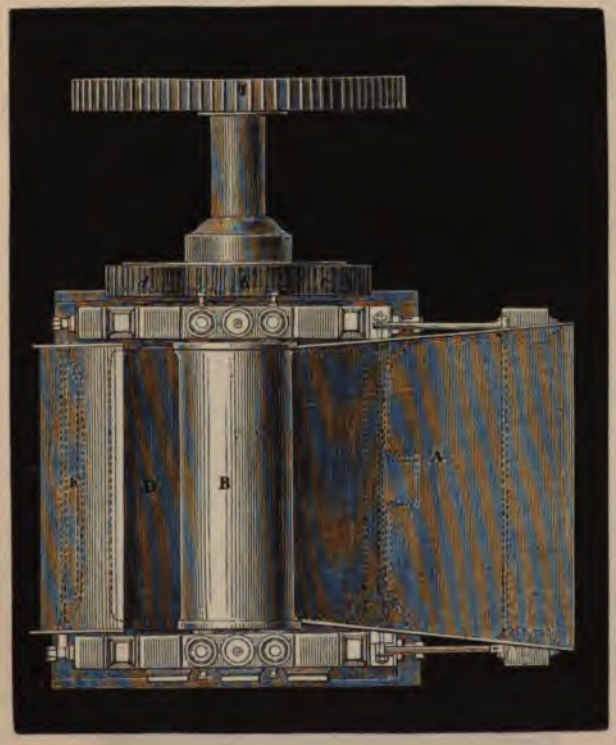
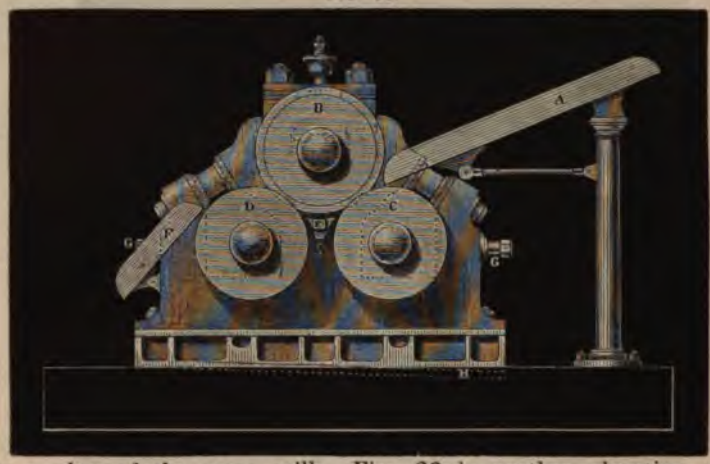


FIG. 65.



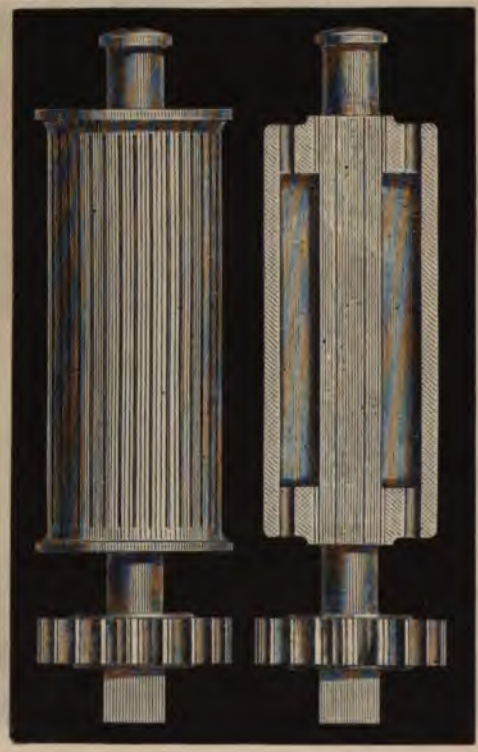
toothed wheels keyed on to the shaft of each roller. Fig. 65

FIG. 66.



is a plan of the same mill. Fig. 66 is another elevation, in

FIG. 67. FIG. 68.



which the nearest side frame has been removed, in order to show the position of the rollers. Fig. 67 is a drawing of the top roller with the wheel attached, by means of which it communicates motion to the two lower rollers. In this roller are slight grooves, for the purpose of more severely biting the canes in their passage through the rollers. These grooves are some-

FIG. 69.

FIG. 70.

times omitted, as they have a tendenc .o tear the fibre of the cane, and render it unfit for fuel. Fig. 68 exhibits a section of the bottom rollers, showing the way the shaft is attached. It also shows the cog-wheel, corresponding to the similar one on the shaft of the top roller, into which it works. Fig. 69 is an end view of this cog-wheel, and shows the way it is keyed on to the shaft. Fig. 70 is an end view of the top roller, showing the way the rollers are fixed to the shafts.

FIG. 71.

Fig. 71 is the plan, and Fig. 72 an end view of the turn-plate, which is placed between the two bottom rollers, in order to guide the canes in their passage after having received their first squeeze. This turn-plate is perforated, in order to allow the juice to drop through, and find its way to the bottom of the bed-plate of the mill, which forms a sloping cistern, from whence the juice runs into another cistern previously to being clarified. The following letters are applicable to the Figs. 64, 65, and 66. The canes are first laid as evenly as possible over the surface of the feeding tray *A*, down which they pass, through the rollers *B* and *C*, over the turn-plate *E*, and through the rollers *B* and *D*. The trash being

FIG. 72.

delivered at the delivery tray *F*, and the expressed juice finding its way through the perforation in the turn-plate to the inclined bed-plate *H*. *G G* are screws for regulating the distances between the rollers.

In Fig. 65 the view of the roller *C* is obscured by the feeding trough, which lies immediately over it. *I* is the wheel, by means of which the motive power is communicated to the top roller, and *b*, *c*, *d*, are the three small cog-wheels attached to each of the rollers *B*, *C*, *D*, for communicating motion to one another.

It will be seen, that in this arrangement of the mill the canes are squeezed twice. 1. Between the first bottom roller and the top one; and 2. between the top roller and the other bottom one. The first pressure having the effect of reducing the mass of canes to a uniform thickness preparatory to their undergoing the second and more powerful pressure. The distances between the rollers can be regulated by screws. The canes should be distributed as equally as possible over the whole surface of the mill, and not, as is often the case, inserted in a heap in one spot. Indeed, instances often occur of the workmen not even taking the trouble to remove the ligatures with which the canes have been bound together. In order to lessen the risk of fracture in the rollers, which would be the result of such carelessness, friction clutches are sometimes attached, so that when the strain on the rollers exceeds a certain amount they cease acting.

The following sketch, Fig. 73, of another sugar-mill will on inspection explain the peculiarity of its construction and mode of action.

Mr. Bessemer objects, upon the following grounds, to the use of the roller press:

In the first place, when rollers are used in expressing cane juice, the time allowed for the pressure exerted upon the canes is too short. When rollers of 2 feet in diameter are making five revolutions per minute, their surfaces, and consequently anything passing between them, must be moving at a rate exceeding 6 inches per second; if, therefore, we assume the effective pressure of the cane to extend to 3 lineal inches at one time, it is clear that 'one half' of a 'second only' is employed in the expression of the juice from each portion of cane, as it is successively brought under operation—a period wholly inadequate to effect the displacement of the fluid from the congeries of cells in which it is contained; neither can this defect be overcome by any alteration in the position or arrangement of the rollers.

FIG. 73.

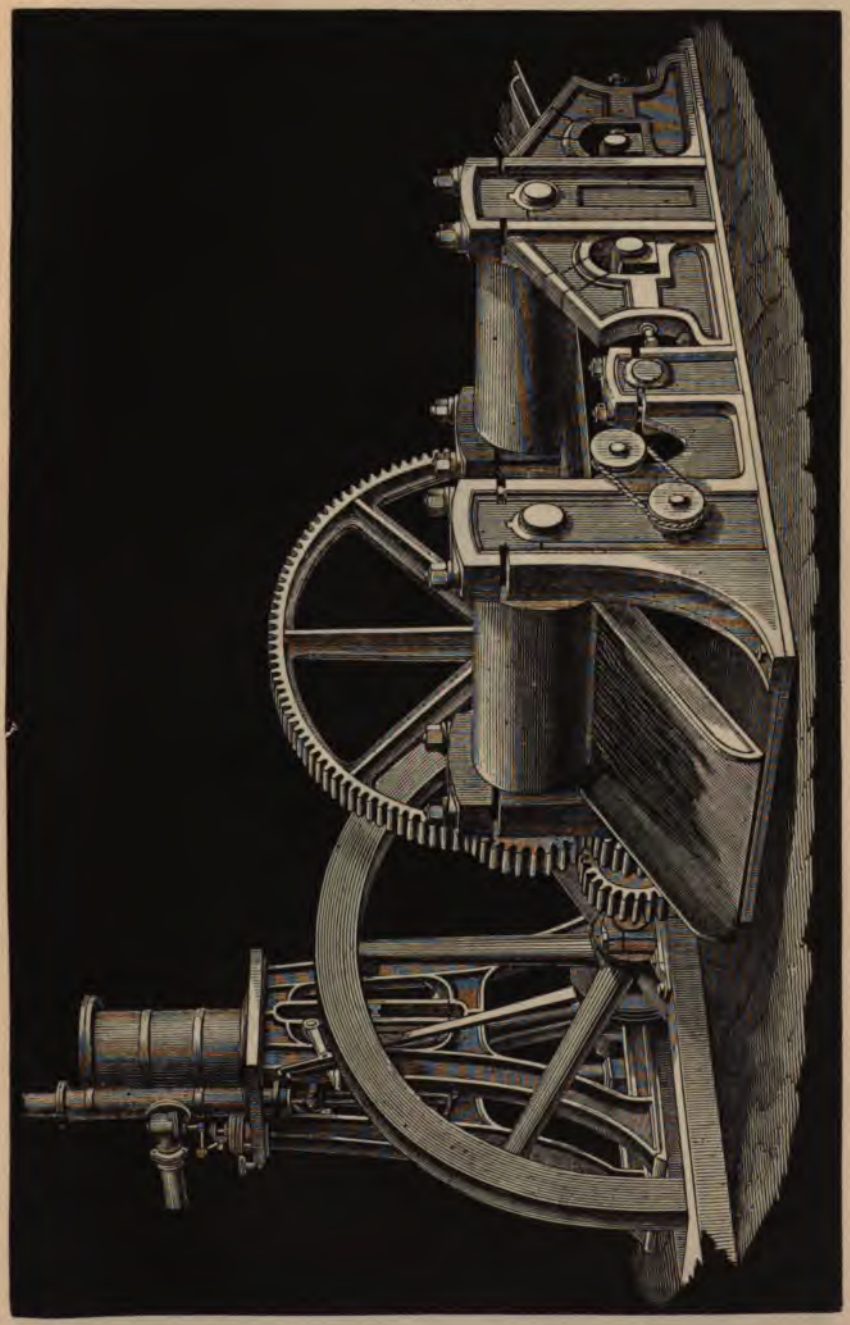
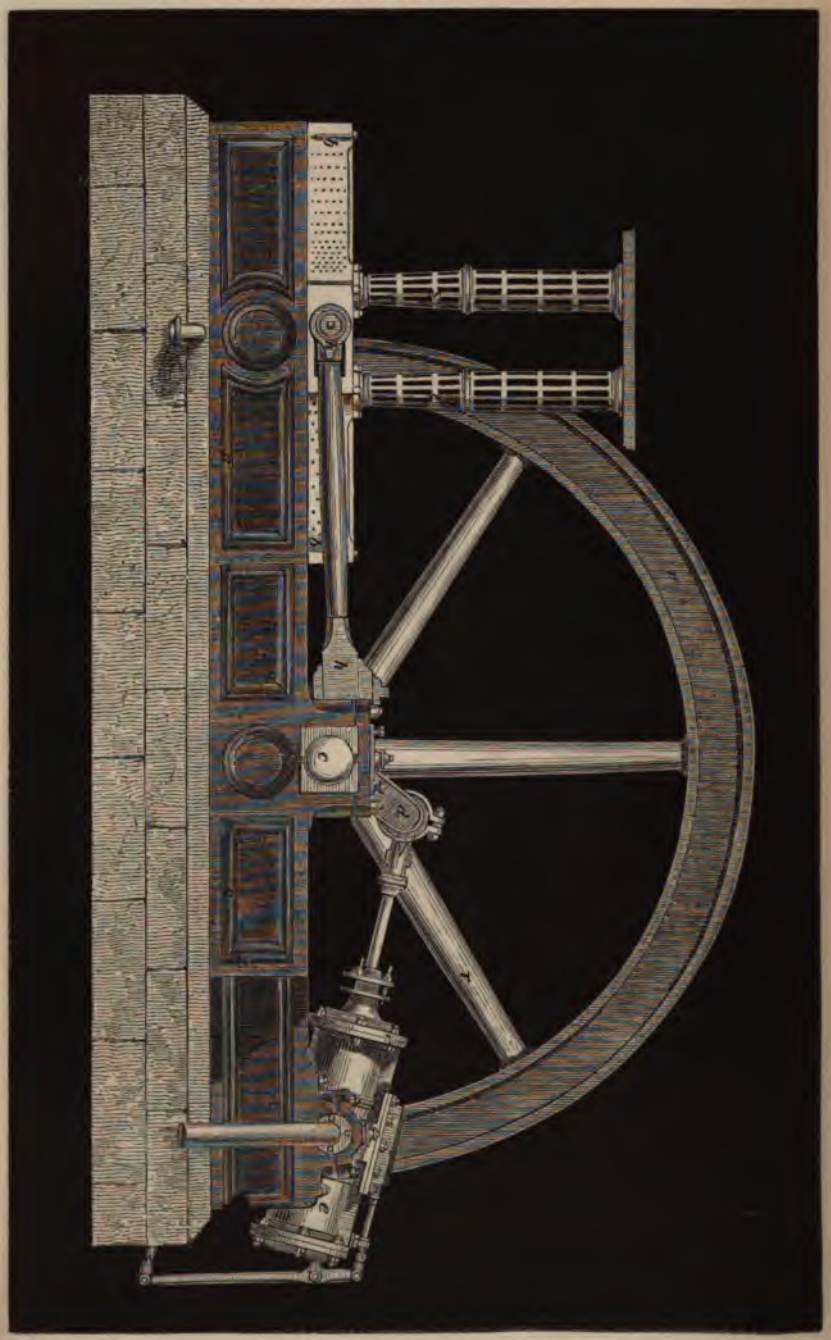


FIG. 74.



Another and a very serious defect in the operation of the roller-mill, is the extraordinary facility it affords for the 'reabsorption' of the juice after it has been expressed. The pressure on a cane, while passing between the rollers of a mill, will always be in proportion to the relative thickness or diameter of the cane, and the amount of space between the rollers; but the amount of pressure exerted upon the different parts of a cane is far from being equal, since the rind and knots are more hard and woody than the rest of the cane, and therefore subjected to a much heavier pressure than the intermediate parts, which are composed of a soft cellular substance and juice; and thus it is that so much chlorophyll, and other objectionable matters, are expressed, the juice becoming greatly contaminated, and the power of the mill diminished.

Mr. Bessemer proposes an entirely new press to obviate these defects:

Fig. 74 represents a side elevation of the cane press.

Fig. 75, a longitudinal section.

Fig. 76 a plan, or bird's-eye view of the same.

'*a*' is a strong iron frame or bed-plate, cast entirely in one piece, and forming the only frame both of the steam-engine and the press, which are, in this case, combined, so as to form but 'one' apparatus, requiring no intermediate gearing therefore to connect them.

'*b*' is a rectangular gun-metal tube or trunk, from 6 to 12 inches in height, and 3 inches in width; there are two or more of these tubes placed beside each other, and firmly secured to the bed-plate '*a*,' which is partitioned off at this end of the apparatus, and forms a cistern for the reception of the juice in the centre of the machine. There is a strong wrought-iron crankshaft '*c*,' having three throws formed upon it; the central throw '*d*' is much longer than the others, and is connected directly to the piston-rod of the oscillating steam cylinder '*e*'; the other two crank-throws '*f*,' are of much less length than the central one, on each side of which one of them is placed, at right angles with it; the tubes '*b*' have slots in their sides, through which a cross-head '*g*' passes, the outer ends of which fit into openings made in the ends of the stout connecting rods '*h*,' the opposite ends of the connecting rods being attached, in the usual manner to the short crank-throws '*f*'; there are also solid pistons, or plungers '*n*,' fitted to the inside of the tubes '*b*,' through which the cross-

FIG. 75.

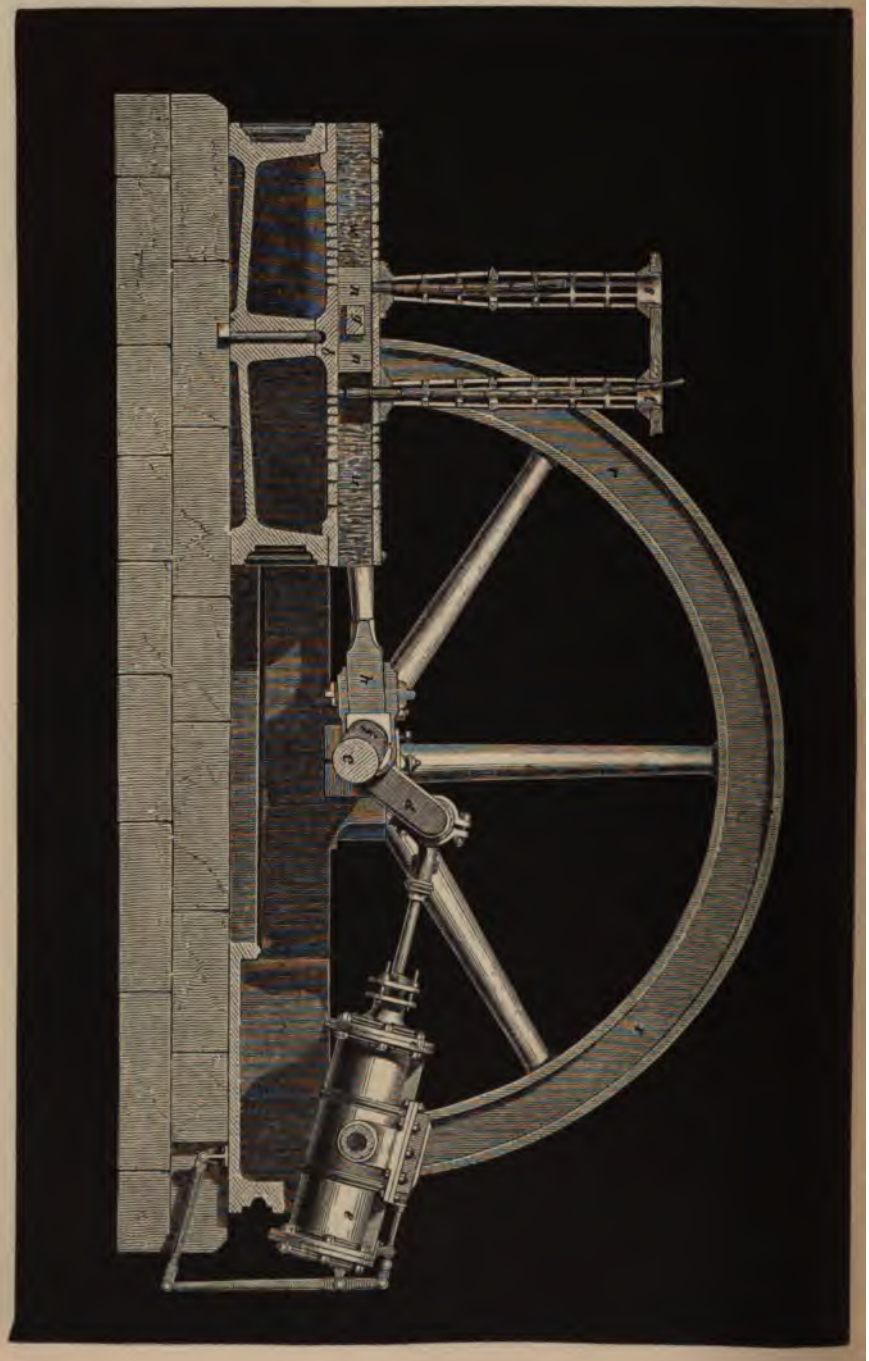
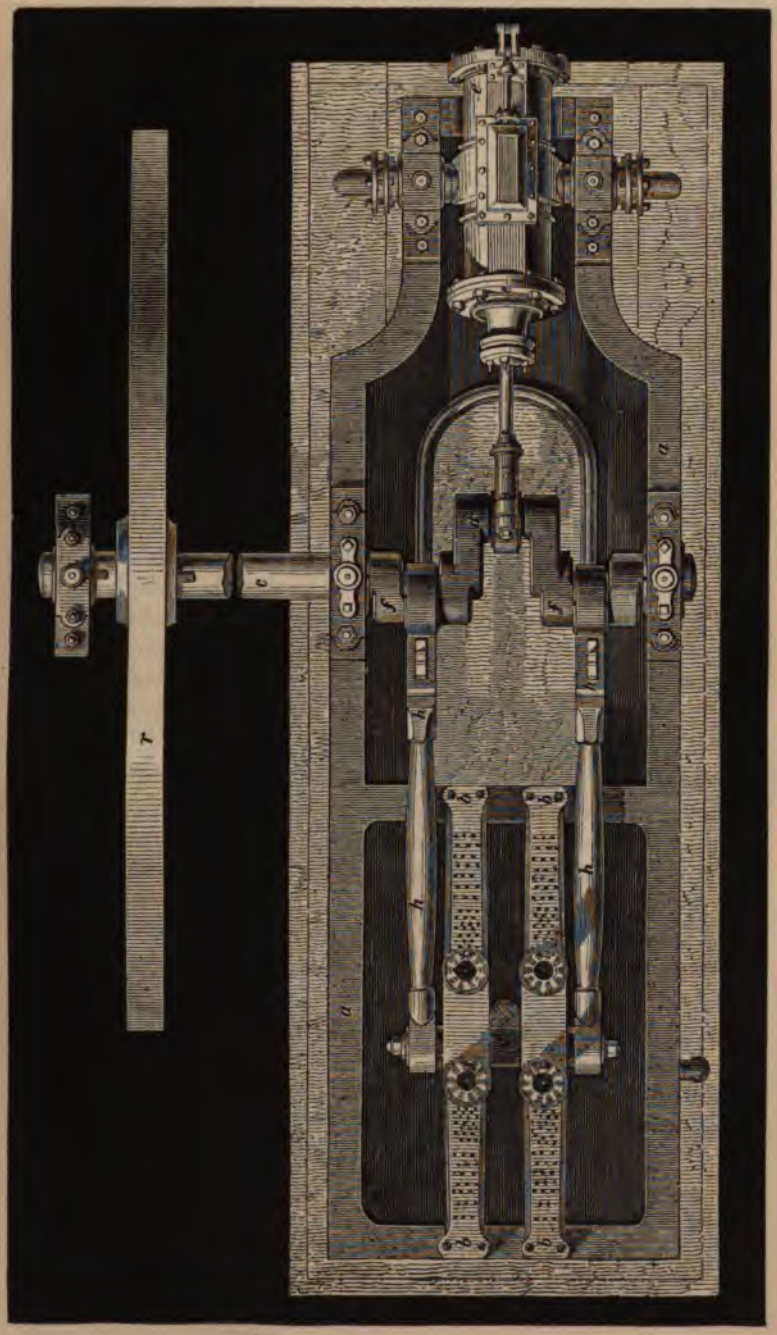


FIG. 76.



head passes, so that, whenever the steam piston gives motion to the crank, a reciprocating motion will be communicated to the plungers '*n*,' the speed of which will be regulated by the fly-wheel '*r*,' which is placed at some distance back from the machine, the crank shaft being elongated for the purpose. The gun-metal tubes, which are made of considerable strength, are perforated on every side by small conical holes, the interior portion of the perforation being the smaller; so that should any matter at any time clog it, the overflow of juice ensure its removal. It has been ascertained, by repeated experiments, that the friction against the smooth parallel interior of the tubes offers sufficient resistance to the progress of the cane, to ensure the entire juice being expressed from each individual piece forming the mass of cane occupying the tubes, before it can be released from pressure by being ejected from their open ends.

When steam is admitted into the cylinder '*e*,' its piston acting on the crank-shaft '*d*,' will, by means of the connecting-rods '*h*,' give a reciprocating motion to the plungers '*n*,' which will move through a much smaller space, and at a much less velocity, than the steam piston, exerting thereby a powerful, though steady, pressure upon the cane within the tubes. It will be observed that the crank-throws which actuate the plungers '*n*,' are placed at right angles with the throw in connection with the steam piston; it follows, that, as the steam piston acquires its most powerful position, the throws which actuate the plungers '*n*,' will assume a position nearly horizontal, and in a line with the respective connecting-rods, by which the lever power, which they exert, will be immensely increased; and the mass of canes compressed within the tubes, yielding to the force thus brought to bear upon them, will be reduced to a state approaching to absolute dryness. The same advantageous position of the steam piston and plungers takes place at each end of the stroke. It will be also evident, that, when the plungers '*n*' are at half stroke, and require but a very small amount of force to produce motion in them, the throw in connection with the steam piston will be passing its dead point, and thus the varying resistance of the cane press is made to adapt itself perfectly to the motive power, which necessarily varies greatly throughout every portion of the revolution. Above the tubes are the hoppers '*s*' and '*t*,' in which the canes are placed at the commencement of the operation; and thus, whenever the various parts of the machine assume the position shown in the

sectional engraving, the cane occupying the hopper '*t*' will fall down as there represented; and as the plunger makes its stroke in the direction of the crank, the end of the plunger will cut off from the cane a piece just equal to the height of the tube, while its further progress will force the newly-cut portion against the mass '*u*,' whereby the greater part of the juice will be expressed; but as the cane contains a certain portion of solid matter, it follows that the plunger, in finishing the stroke, will move forward the whole mass '*u*' a distance equal to that occupied by the solid portion of the newly-interposed piece; this movement of the mass displacing at the open end of the tube an equal portion of the mass occupying it. During the cutting off and pressing of the piece described, the plunger will have moved from under the hopper '*s*,' and the cane in it will also have fallen down into the tube; the reverse motion of the plunger will also cut off a length from it, and force it against the mass '*w*,' as represented in the engraving, expressing the juice in the manner before described; the alternate motion of the plunger thus acting on two pieces of cane at every stroke, and a similar operation also taking place simultaneously in as many tubes as may be placed side by side over the cistern. The upper ends of the hoppers, or feeding tubes, '*s*' and '*t*,' are inserted into the floor of a small feeding stage, not represented in the engravings, because its size and position will much depend on the dimensions of the mill-house and other local circumstances. The canes may be conveyed to this stage by a carrier in the usual manner, and a man standing upon it will drop them into the feeding hoppers, an operation unattended with the danger which is, more or less, incurred in feeding the roller-mill.

In immediate connection with the cistern into which the juice falls from the pressing tubes, there is a self-regulating heating apparatus, not shown in the engravings, whereby the juice, within two minutes after its expression from the cane, acquires such a degree of heat as is necessary for the defecating process; the heat thus imparted is entirely governed by a self-acting contrivance, by which the precise heat required may at all times be obtained, and which being accomplished out of contact with the atmosphere, the juice is much less likely to acidify; the heat is obtained from the waste steam of the engine working the press. The megass or bagass from the cane-press is in a most favourable condition for fuel, being free from the small pithy fragments, which, as has before been

observed, so materially obstruct combustion; nor is it mixed with the long, unwieldy pieces, as from the old mills; but, being in a highly-decomposed state, and every piece being of equal length, it almost resembles prepared fire-wood, and is, in that precise condition, calculated to ensure a vivid combustion under the coppers. However free from moisture the internal tissue of the cane may be, on its escape from the tube, there is still a certain degree of moisture in the rind which may be found sufficient to prevent its burning readily; to remedy this, the megass falls upon a megass-carrier of improved construction, by which it is conveyed through a drying apparatus, and delivered at the furnace door of the evaporating pans in a perfectly dry state; the heat it has acquired during its progress, renders it in a condition peculiarly favourable for combustion.

From what has been said of the peculiar operation of the cane-press, the mode adopted for heating the juice, on its passage to the defecating vessel, and the manner in which the cane trash is cut into convenient lengths, compressed, dried, and eventually carried to the mouth of the furnace, in the most perfect state for burning, will have been sufficiently understood; but, in order that the operations should be fully tested, experiments have been made with a cane-press, fitted up, with engine combined, from which machine the engravings have been made. The canes for the experiments were obtained from Madeira, and reached this country generally in good condition. The quantity of juice which this small apparatus has been found capable of expressing exceeds six hundred imperial gallons per hour; the juice is much more free from small broken fragments than when the pressure is performed by rollers, while the quantity of colouring matter extracted is extremely small, owing to the causes before stated; but by far the most important result, which is now fully established, is the quantity, or rather the percentage, of the juice obtained. In the first experiment, made immediately on the arrival of a small supply of cane, the produce exceeded 80 per cent; in an experiment, made when the canes had been four months cut, 73¾ per cent was expressed; and in a public experiment, when the canes were still further deteriorated, and had, in some instances, become discoloured, nay, rotten, 65½ per cent was obtained.

The mill is sometimes elevated above the ground, so as to allow the expressed juice to run at once to the next stage of the

process. The canes are, in this case, carried up to the mill by a cane-carrier. The mill is, however, generally upon the ground-floor, and the juice is then raised to the required height by means of force-pumps; or, in order to avoid agitation, which is always injurious to cane-juice, it is admitted into a vessel called a Monte-jus, from which it is forced up a pipe, by means of the pressure of steam acting upon the surface of the liquor.

FIG. 77.

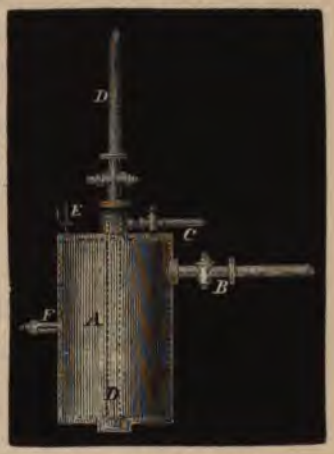


Fig. 77 is a drawing of a Monte-jus. *A* is the vessel for receiving the juice to be elevated to the required height. It is charged through the pipe and cock *B*. *C* is the pipe for supplying the steam that is to force the juice up the pipe *D* to its destination; *E* is an air-cock, through which the air escapes upon the admission of the juice; the pipe attached to the cock dips two or three inches below the top of the cylinder, so that the juice never rises above that height, the space above being filled with air, which acts as a cushion, placing itself between the steam and the cane-juice, and being a non-conductor of heat, it prevents the juice from becoming heated, and consequently obviates the risk of ebullition.

F is a man-hole for cleaning out the monte-jus, when necessary.

It will be seen that the pipe *D* is not only continued to the bottom of the receving-vessel, but also dips into a small sunken receptacle, in order that none of the juice may remain spread over the surface of the bottom, but that it may accumulate in this receptacle.

M. Dupuy states,* as the mean result of two experiments made by him in Guadaloupe, that 40 per cent of the sugar existing in the canes is never extracted, but is left in the bagass, or cane-trash. Allowing for considerable exaggerations in this estimate, there still can be no doubt that great improvements remain to be effected in the method of expressing the juice from the canes. Much might probably be done by greater care being taken that

* Sucre de Canne, Traité de Chimie, par M. Dumas.

the canes are equally distributed over the rollers, so as to obtain an even pressure upon them, and by passing them a second time through the mill, having previously dipped them in water. The great objection to this has hitherto been that the second operation has had the effect of too much lacerating the trash, and rendering it unfit for fuel, and incapable of producing the long flame required for the copper-wall, in the old process of sugar manufacture. This objection is however obviated by the use of steam-heat for evaporation, coals being used as fuel, the trash may be applied to the far more valuable purpose of forming manure for future crops, the size of the cane being in that case no object.

Improved Compensating Cane Mill, with Cane and Megas Carriers attached. — In the ordinary three-roller horizontal mill, the two bottom rollers work in brass bushes, fitted into the cheeks of the supporting frame-work. The distances between the rollers are regulated by adjusting screws; these screws do not, however, make any provision for the constantly-varying quantities of canes that pass through the mill, from its being unevenly supplied; and consequently, when the supply of canes diminishes, they are not adequately pressed; and when a great number suddenly present themselves, the mill is very much strained, if not actually broken. Several attempts have been made to remedy these defects, but all the methods hitherto discovered are liable to great objections. Friction-clutches are among the best of these remedial measures, but they are very uncertain in their action, and at the best only partially effect their purpose. Neither are they self-acting, for if the mill be overloaded, the only effect of the clutches is to cause the rollers to cease revolving, and the surplus canes between them can only be removed by reversing the engine. Again, if the mill be not sufficiently supplied, the canes are not properly crushed, and a considerable quantity of juice is thus lost. A plan that completely removes all the objections attaching to the other methods, has been invented by Mr. Moore, late of Demerara, but now in the office of Messrs. Pontifex and Wood, who has obligingly furnished us with the following beautiful illustrations of his ingenious invention. Mr. Moore's invention consists in allowing the bushes, in which the two lower rollers revolve when the mill is overstrained, to slide back in their frame-work, and thus increase the distance between the rolls; thereby adjusting the space between them to the work they have to perform, at the same time ensuring the mill against

fracture, and obtaining a more complete extraction of the juice. The required pressure upon the canes is by a heavily-weighted lever; the rollers are also prevented from wearing hollow in the centre, or least-supported part, the effect of the violent strain upon them caused by too great a quantity of canes passing between them.

In Fig. 78 an Elevation and Plan of this new process is shown.

A is the shaft of a condensing steam-engine, of sixteen-horse power, making twenty-four revolutions per minute.

B is a pinion on the engine shaft, for driving the mill.

C is an extra crank on the engine-shaft, for working a pump, &c.

D the driving-wheel, 12 feet 5 inches in diameter.

E a clutch, with a lever for disconnecting the mill from the driving-wheel shaft.

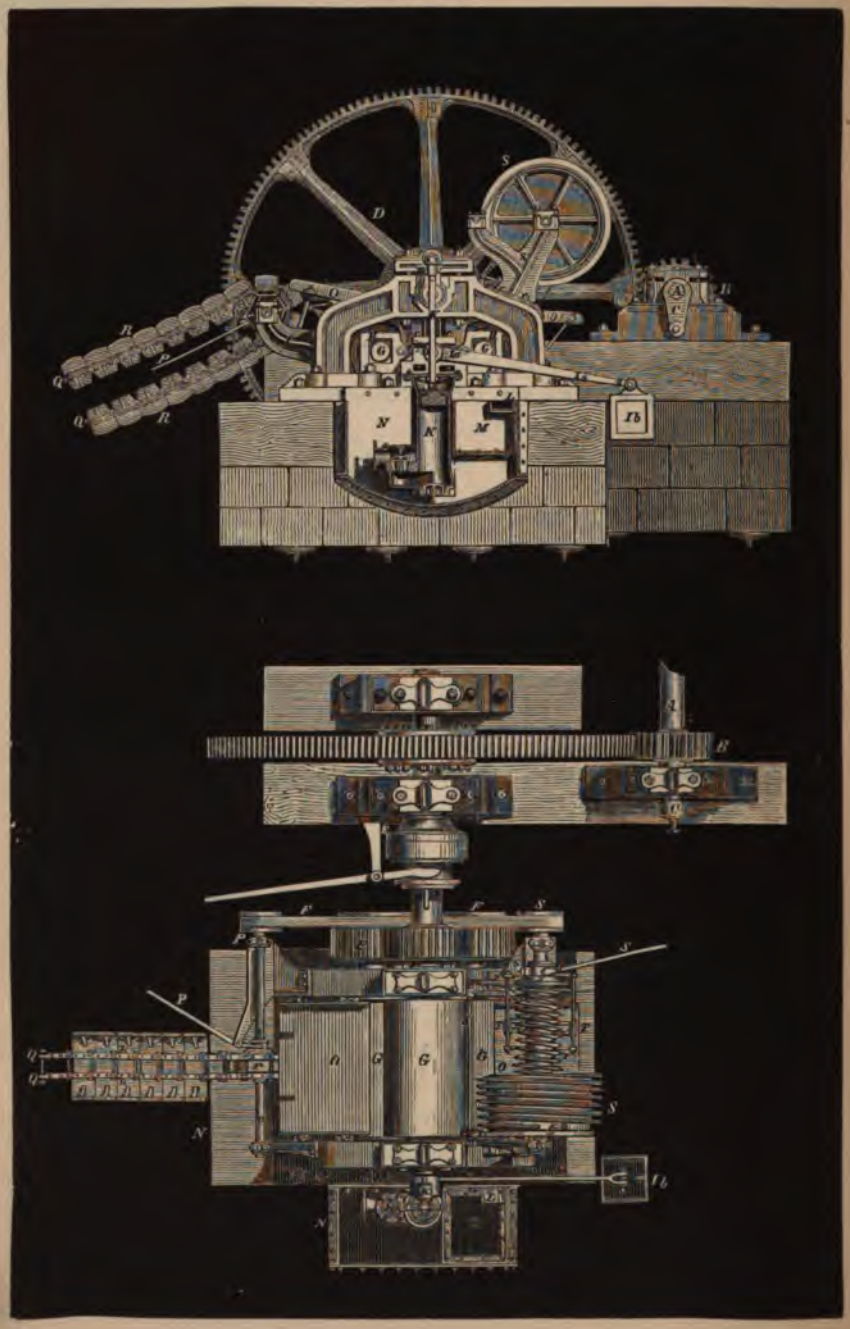
F three roller pinions, the upper one communicating motion to the two lower ones.

G the rollers, each having a bearing in the middle (not shown) for lessening the strain upon them.

H cast-iron boxes, fitted with brass bushes, for the journals of the lower rollers to work in. These boxes are made to slide upon flat surfaces, left upon the cheeks or side-frames; so that when the pressure against the roller is excessive, the boxes are forced back, thus widening the space between the rollers, and equalising the pressure upon the canes.

I a wrought-iron shaft, running the whole length of the mill, under the centre of the upper roller, and on a level with the centres of the two lower ones, having a bearing at each end. Opposite the centres of the boxes *H*, double cranks (dotted in the Elevation, Fig. 78) are keyed on to the shaft, making an angle, with a horizontal line passing through its centre. The cranks are connected with the boxes by short links. A lever, *I a*, 6 feet long, is fixed to one end of this shaft; to the extreme end of this lever is hung a heavy weight, *I b*, which, acting upon the double cranks, forces them to approach towards a vertical position; and thus, by means of the short links acting upon the boxes *H*, force the rollers closer together. The cranks are so arranged, that at no time can the distance between the rollers exceed $\frac{5}{8}$ths of an inch for the feeding side, and $\frac{3}{8}$ths for the delivery side. A weight of 175 lbs. at the end of the lever, is made to balance a pressure of 6,600 lbs. against each roller, or an outward horizontal thrust

FIG. 78.



to each of 4,200 lbs., equivalent to twelve-horse power. This weight, besides giving the pressure upon the canes, causes the rollers to assume their former position, as soon as the extra quantity of canes has passed through them.

Mr. Moore has also effected considerable improvements in the arrangement of the cane and megas carriers.

The cane carrier generally consists of a number of flat boards, jointed together, to form a kind of endless chain, which works up an inclined wooden frame, or bed, having a flange or low rail running up the sides, to prevent the canes from falling off the carrier. The friction of the carrier against the sides and bottom of the frame-work causes a great strain, and throws considerable extra work upon the engine, besides creating much wear and tear in the carrier. These objections are, in the present instance, remedied by making the flange for supporting the canes upon the chain of boards, instead of upon the supporting frame-work; thus doing away with the great amount of friction throughout the whole length of the frame-work, and admitting of more lightness in the construction of the machinery, thereby requiring less power of engine.

K is a liquor pump, driven by a crank on the upper roller shaft, for forcing the expressed juice into a cistern above the clarifiers.

L is a trough for collecting the juice, and conveying it to the straining mill, which is furnished with a perforated zinc false bottom, to act as a strainer.

N is a liquor cistern, bolted to the sole-plate of the mill.

O feeding and discharging plates, the inclines of which are adjusted by a screw.

P shaft and toothed tumbler, for driving the cane carrier; the shaft works in bearings on brackets, bolted to the cheeks, and is driven by a belt or pitch chain from the lower roller shaft: the tumbler is carried round by a clutch having a handle, by which the carrier may be disconnected.

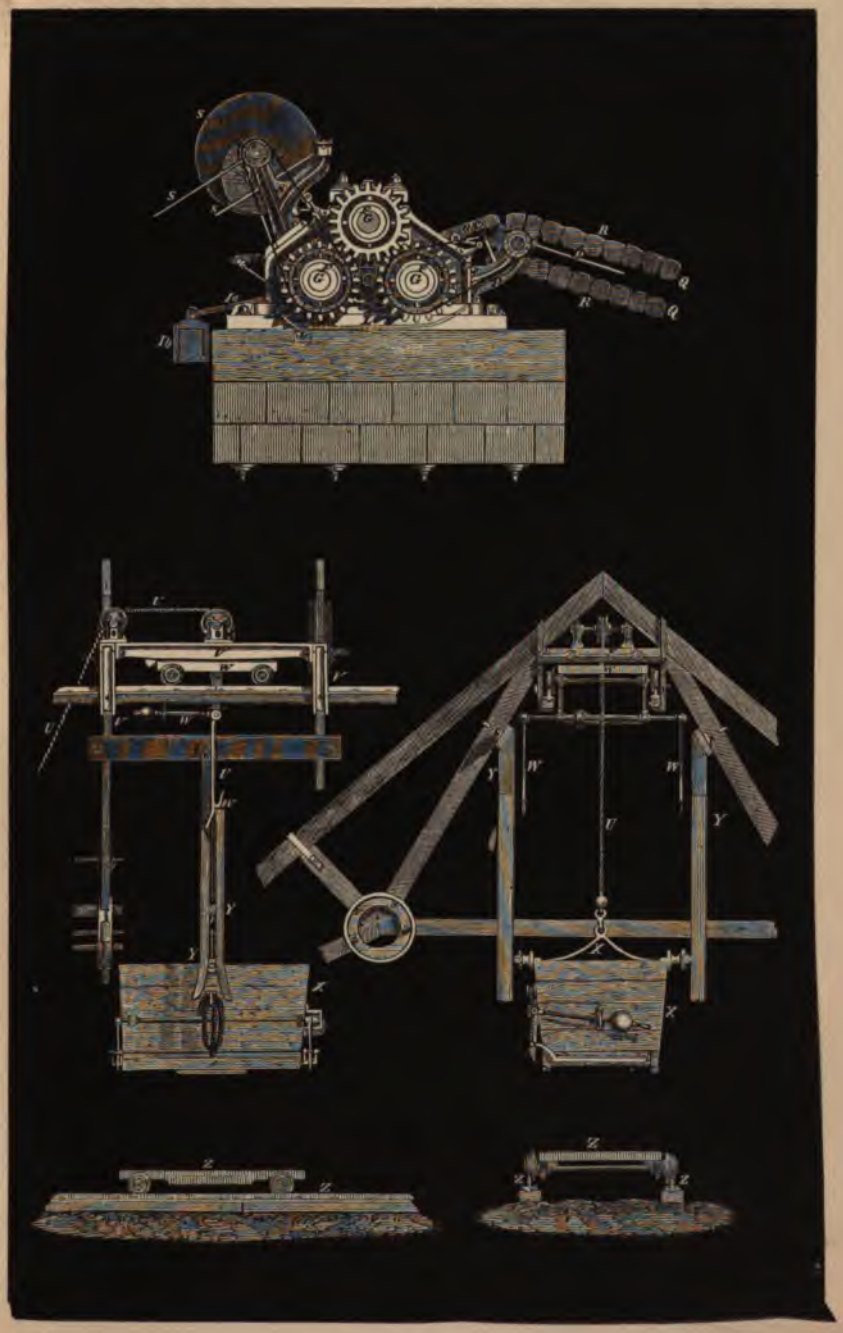
Q is the chain for giving motion to the cane carrier; it is worked by the tumbler. Friction rollers are placed at intervals, to lessen the strain on the chain and tumbler. The outer end of the chain works over a second tumbler (not shown in the drawing); the plummer blocks of this tumbler are furnished with regulating screws for tightening the chain.

R the carrier boards rivetted to the chains, and having a double

flange on each end; the upper one to prevent the canes from falling off, and the under one to admit of a bracket for keeping the upper one in its place. The megas or trash, as the crushed canes are indifferently called, is generally raised to the top of the megas-house in a carriage, drawn up an inclined plane by a rope attached to the carriage; the rope passes through a pulley in the roof, and is wound round a drum attached to the engine. This arrangement takes up a great deal of room, is expensive to erect, and is not self-acting. Mr. Moore proposes to supersede it by substituting an elevator for the inclined plane, as it will occupy less space, and as less iron-work is required in the construction of the carriage or box, it may be made much lighter, and thus consume less power of the engine. These objects are accomplished in the following manner:

When the juice has been expressed from the canes, the megas is run from the mill in a carriage *Z* (Fig. 79), travelling upon a short railing to a spot from whence it is raised up the wooden guides *Y* to the top of the megas-house by an elevator. A screw drum *S* (Fig. 78), bolted to the cheeks of the mill, is driven by a belt or pitch chain from the lower roller shaft; it is carried round by a clutch, which may be thrown out of gear by means of a handle. A rope *U*, passing over pulleys, works in the screw, and is so arranged that it makes as many turns on the large part of the drum as will nearly raise the megas-box *X* (Fig. 79), to which it is attached, to the top of the house; the remaining short distance is accomplished by the rope making one or two turns on the smaller diameter of the drum. A ring *T* (Fig. 78) passes round clear of the drum, and has attached to it two small rollers, opposite to one another, working in the screw; it is kept in its position by two rods, on which it slides. Whilst the drum has been raising the megas-box, it has also carried forward the ring, till the box has reached its required height, when the ring forces out the clutch that turns the drum, and allows the box to fall into the hooked rods, suspended on either side from the lower part of a travelling carriage *W*, running on a railway attached to the top of the house by the cast-iron brackets *V*. These rods are pushed aside by the pivots by which the carriage is suspended in the hooks, as it rises past them; they are immediately made to resume their original position by the weight of the cast-iron ball. A friction-strap is attached to the end of the drum, for preventing the too rapid descent of the box when empty. The bottom of the

FIG. 79.



megas-box *X* works on hinges, and is fastened by a catch, withdrawable by means of a lever; when the box has reached its destination, the megas falls through the bottom, which is then closed by a rope.

The whole of the connections to the mill here described are bolted to one sole plate, bedded on square logs. The mill is calculated to express 10,000 gallons of juice per day, from good average canes. With an average quality of juice, this would make five hogsheads of sugar.

The expressed cane-straw is dried, and used as fuel, in the ordinary manner.

Produce in juice.—The foregoing analyses of Henry indicate that there is still left in the bagass from $\frac{3}{13}$ths to $\frac{4}{11}$ths, therefore $\frac{1}{6}$th in mean, of the entire quantity of sugar in the cane. While, according to the published analyses, there exist in the fresh cane from 84 to 90 per cent of juice, only $\frac{2}{3}$rds to $\frac{6}{7}$ths of that quantity are obtained in the boiling-houses from the presses.

Casaseca obtained, in experiments conducted at the Havanna, from 100 parts of so-called crystalline sugar-cane, 65 parts; from striped cane, 55 parts; and, lastly, from Otaheite cane, 43½ parts of bagass.

Dupuy observed, in a series of experiments at Guadaloupe, the following proportion of bagass to juice, as expressed by the presses then in use:

As a minimum quantity,	55 parts of juice	to	45 parts of bagasse.
As a maximum „	68½ „		31.5 „
As the mean of 33 experiments . . .	59½ „		40½ „

or $\frac{3}{5}$rds of the entire juice.

The character of the internal parts of the sugar-cane is not that of a soft pith, as is the case in beet, but it is both woody and spongy like a Spanish cane, and therefore ill adapted to yield to pressure; the action of the press is still further impeded by the hard rind which envelopes the cane. Although it is certain that more powerful machines express an appreciably larger quantity of juice, yet it can be predicted that the average loss of juice will never be reduced to an unimportant quantity by any improvements in the machinery. The proposed plan of soaking the bagasse in water immediately after it has left the press, and then again passing it under the rollers has generally been found impracticable from the want of water and wood, on most plantations.

All the methods proposed for increasing the produce of juice which leave the expressed cane (by cutting it small) in an unfit state for fuel, have been rejected by the colonists; beechwood, for instance, is rendered useless as fuel, when converted into saw-dust.

Bagass the fuel of the Colonies.—The sugar-cane is not only the source of sugar to the boiling establishments, but likewise, after being pressed and dried, it is their principal fuel.

The bagass is for this reason of the greatest importance in the colonial sugar-boiling establishments, which are otherwise scantily supplied with fuel, and is absolutely essential to the very existence of those that are altogether deprived of wood and coal. The woody parts of the cane are rather more than sufficient to evaporate the mass of water in which the sugar is dissolved. Many of those who are unacquainted with colonial interests have proposed, as the only efficient mode of overcoming the difficulty caused by a scarcity of fuel, that, instead of expressing sugar, the cane should be cut into slices, dried, and thus sent to Europe, where the superior machinery and abundant supply of fuel would certainly afford a larger produce. In the meantime, there is not a sufficient supply of fuel in many of the colonies to dry the cane, and this would therefore require to be first imported.

From the foregoing remarks, it appears that only $\frac{2}{3}$rds of the juice are actually obtained by the ordinary presses, and these only contain 12 per cent of the sugar contained in the fresh cane; so that 6 per cent of sugar is left in the bagass, and this is burned with the woody matter under the boiling-pans; so that when eighty millions of kilos. of raw sugar are imported into France, forty millions of kilos. are burned in producing them, and the value of these would amount to about twenty millions of francs.

Nature of the juice.—We have still to review the contents and qualities of the juices, as yielded by the presses for boiling.

There have been found by:	Casaseca.	Peligot.	Plague.
In the juice of	Creole cane from Cuba.	Otaheite cane from Martinique.	Sugar cane from Martinique.
Water	78.80	79.6	78.30
Sugar (crystallizable)	20.94	20.00	21.50
Other vegetable matters	0.12	0.20	0.80
Mineral substances (ashes)	0.14	0.21	in considerable quantity.

The entire amount of sugar is of the crystallizable variety; the other vegetable matters are albumen, about $\frac{7}{1000}$ths of gum, and a peculiar, very imperfectly described substance, resembling gluten or vegetable gelatin, but which is said to be devoid of nitrogen (?). This is the substance deposited in great quantities in the vats in which sugar is allowed to ferment for the production of rum; its presence is ascribed principally to the great changeability of the saccharine juice. Besides these, there is cerosin and green vegetable wax, about $\frac{3}{1000}$ths or $\frac{4}{1000}$ths. The mineral ingredients are similar to those in other plants and vegetable juices—sulphate of lime, sulphate of potash, chloride of potassium, chloride of sodium, phosphate of lime, silica, &c.

The juice of the sugar-cane is sometimes colourless, but is generally of a yellow colour, rendered turbid by greyish globules of suspended matter. Its taste is agreeable, although somewhat insipid, and it possesses a peculiar balsamic odour.

b.) Mode of working up the juice upon the old system.

The clarification, or defecation.—The operations connected with the juice are performed in a system consisting of five pans, or rather iron boilers, walled together in a row, and heated by one common fire: the whole is called the copper-wall. From the juice reservoir, below the press, the juice is allowed to flow at once into the clarifying pan, which is the fifth of the row, and the furthest removed from the fire, while at the same time it is the largest, and should be capable of holding the entire quantity of juice. In some boiling-houses this is done immediately after the pressing, but in others is very injudiciously postponed for several hours. The clarification is performed with milk of lime, which is measured out in the proper quantities by a vessel divided into inches. The inch corresponds to $4\frac{1}{4}$ oz. of milk of lime, and there is never less than five, or more than ten inches, required to clarify 1800 liters, or about $\frac{1}{1000}$th to $\frac{3}{1000}$ths of the entire weight of the juice. The simple application of heat effects coagulation. Avequin found in the precipitate obtained in this manner from the juice of the striped sugar-cane:

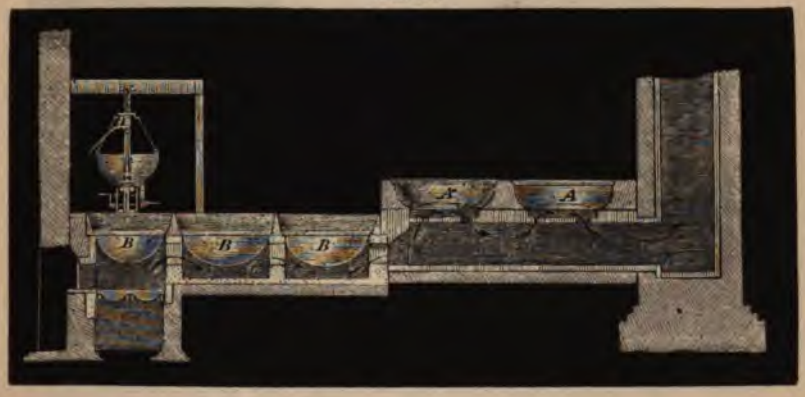
Gum, resembling cherry-gum . . .	50.25
Green matter (chlorophyll) . . .	10.05
Albumen (with particles of woody fibre) .	22.78
Phosphate of lime	3.35
Silica	14.07
	100.50

Ten liters of juice yielded 15 grammes of this precipitate. The phosphoric acid is originally present in the form of an acid salt; for this reason, copper vessels are speedily attacked with the formation of phosphate of copper. The lime converts this salt into a basic phosphate; it combines with the silica and the organic matters, and very materially assists the precipitation of foreign ingredients.

A dense impure scum collects on the surface of the liquid as the process proceeds, which breaks up only by boiling, but does not separate entirely, and can easily be removed with a skimmer. The juice loses from 4 to 5 per cent by skimming.

The old method of manufacturing sugar is represented in Fig. 80. The juice is first admitted into the clarifiers *A*, where

FIG. 80.



the defecation is effected; it then passes through the various-sized teaches *B*, forming the copper-wall, as it is called, till the evaporation is completed. During the progress of the evaporation, an immense quantity of thick scum is being constantly thrown up, which is removed as fast as formed by means of an instrument called a skimmer, which is merely a perforated copper-plate, attached to a handle, the cane-juice escaping through the perforations, and returning to the teaches. This scum is formed almost entirely of pure sugar, that has been decomposed by the heat, but the natural impurities of the juice are mixed with it. It is passed to the molasses-cistern, and is principally converted into rum. Each teach is smaller than the other, to allow for the gradual diminution in the bulk of the juice which is removed from one teach to the other by means of a copper ladle or dipper.

The last and smallest of the series is called a skipping teach (Fig. 81). It is provided with a smaller vessel of exactly the same shape, having a valve at the bottom, worked by a handle. This skipping teach is let down by a crane into the other vessel, and withdraws at once all the sugar from it, which is then conveyed to a wooden vessel called a cooler, and is thence packed in hogsheads, where it is allowed to drain for some weeks. This drainage amounts to about 100 gallons of molasses for every hogshead of sugar; and, in addition to this, large quantities drain away during the conveyance of the sugar to this country; and even then large quantities of molasses, or partially decomposed sugar, still remain to deteriorate the value of the whole.

FIG. 81.

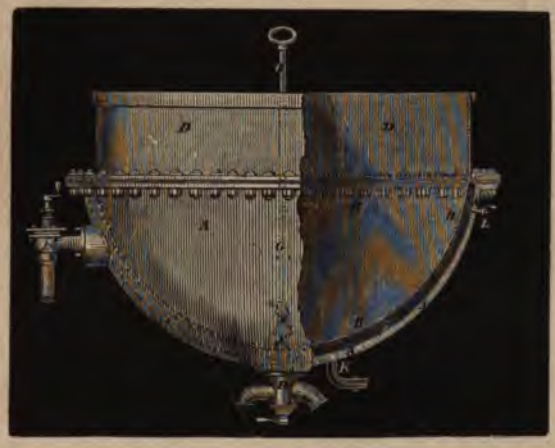
On this plan of making sugar, only one fire, in which trash is burnt, is used for the whole range of coppers; the direction of the flue is shown by the arrows. The skipping teach is not always used, the sugar being sometimes ladled out of the finishing-teach, as from the others. The sugar is much injured by being so constantly ladled, and exposed in small quantities to the action of the atmosphere. In fact, a more elaborate and effectual means of converting pure sugar into molasses and scum than this process presents could hardly by any possibility be conceived. There are several other modifications of the process, but it is not necessary to describe them; they are all tainted, more or less, with the defects of the original process. One of the worst, the *chaudière à bascale*, is described in the "Mechanics' Magazine," for April 14, 1827.

The most recent plan of clarification is as follows:

The expressed juice is raised, by means of the monte-jus, into the vessels in which the clarification or defecation is effected. These vessels consist each of a hemispherical copper pan, surrounded by a cast-iron case or jacket, with a space between the two for the admission of steam, the supply of which is regulated by a valve. On the top of the copper pan is fixed a light-course, or copper band, of from 15 to 18 inches deep, to prevent the scum formed during the process from frothing over.

Fig. 82 is a drawing of the steam clarifier, or defecator. It is shown partly in section, and partly in elevation.

FIG. 82.



A is the outside cast-iron jacket or casing. *B* the inside copper pan, which receives the juice to be clarified. *C* is the space between the two pans for containing the steam that is to heat the juice. *D* is the light-course, or copper-band, at the top. It will be seen that a rim or flange is formed on the bottom of the light-course, and the same on the tops of the copper and iron pans. A flat iron ring is then placed on the top of the two flanges, and the three are firmly secured together by bolts and nuts; red lead having been previously placed between all the surfaces, to make them perfectly tight. *E* is the hollow plug, which is ground into a socket in the iron pan, and communicates with the two-way cock *H*. The plug *E* has a hole in it *F*, through which the clarified juice passes down the hollow of the plug to the smaller of the two ways in the cock *H*. When all the clear liquor has been run off, the plug is removed by means of its handle *G*, and the thick scum and sediment remaining passes away through the larger way of the cock. *I* is the valve for supplying the clarifier with steam, which, when condensed, passes through the pipe *K* to the condense-box. *L* is a cock, through which the air escapes, upon the admission of the steam; it is shut as soon as the steam has driven out all the air before it.

In the proper working of these clarifiers much depends upon their construction, the object being to obtain (in order to insure rapidity of action) as much heating surface as possible, as compared with the capacity, without making the vessels so small as

to require a very great number of them, and thereby greatly increase the cost of machinery. In improperly constructed clarifiers, such as some of those made in France and Belgium, they are sometimes as long as two hours in clarifying, and consequently never succeed in removing all the impurities. This is caused by the increased height of the light-course, so that the contents of the clarifiers are out of all proportion to the heating surface; but by doing this they are enabled to make the machinery somewhat cheaper, as the pan part is by far the most difficult to make, being rolled and hammered out of a solid piece of copper, originally of about the size and shape of an ordinary Cheshire cheese. The juice should be clarified as soon as possible, to obviate the risk of fermentation.

While the clarifiers are being filled, sufficient steam is admitted into the jacket to raise the temperature of the juice to 176° F. The particles that will be found floating on the top of the liquor are then removed, and milk of lime added in sufficient quantities to neutralise the acid in the juice; this is ascertained by dipping blue litmus paper into it at intervals, till it is no longer reddened by immersion. The heat is meanwhile continued, till a scum of from 3 to 4 inches thick, consisting of most of the impurities pre-existing in the cane-juice, has risen to the surface, and appears about to crack: this appearance should present itself in from ten to twelve minutes from the heat being first applied. The steam is then shut off, and the liquor allowed to subside for fifteen or twenty minutes, when the scum will be found to remain at the top; some heavy matter, such as dirt, &c., will have fallen to the bottom, and between them will be a beautifully clear liquid, of a pale straw colour. This clear liquid is separated from the impurities in the following manner:

At the bottom of each clarifier is a hole, into which is ground a hollow plug, removable by means of a long handle. This plug has an aperture in its side, at about 3 or 4 inches from the bottom of the clarifier, below which point all the heavy matter will have accumulated. Attached to the cast-iron jacket, and communicating with the hole in the bottom of the clarifier, is a cock having two ways, the one smaller than the other; the clarification being completed, the cock is turned on, when the clear liquor flows through the aperture in the side of the plug, and out of the small way of the cock, till some of the scum begins to present itself; the cock is then turned on to the larger way, the plug altogether

removed, and the heavy matter at the bottom of the clarifier, together with the scum formed during the process, is swept out through the hole from which the plug has been withdrawn, and conveyed to a cistern, from whence it is placed in bags, and any juice remaining in it is afterwards squeezed out, leaving nothing but a very small proportion of solid impurities behind. When in the clarifiers, the juice should never be allowed to approach a state of ebullition, or to rise above the temperature of 208° to 209° F., or the impurities will become in consequence so intimately mixed with the juice as to prevent their entire separation; the same result follows if the whole process be not speedily conducted.

Another plan for separating the scum from cane juice by centrifugal force will be found described at the end of this chapter.

Boiling.—As soon as the greatest proportion of the scum, which comes to the surface in a compact form is removed, the evaporating or boiling process commences, during which the juice passes upon the old system from one of the remaining four pans to the next, and so on, as long as its volume is diminished, and fresh juice is added. As the pans are often situated at the same level, and not in terraces as in Fig. 80, which is the better and more convenient plan, the juice must be scooped from pan to pan, which causes the loss of much time, wastes much sugar, and spoils more. In the second pan, where the concentration begins, the boiling liquid constantly throws up scum to the surface and rim of the pan, where the negroes collect and return it to the clarifying vessel. From the last pan but one, where it acquires a concentration of 30° B., the juice arrives at the last and smallest pan, where it is boiled down to the point of crystallization. The boiling is kept up in this pan, which is directly over the fire, in a very stormy manner, the cause of which must be ascribed to the formation of panstone, a deposit of lime, 3 or 4 lines in thickness, which attaches itself firmly to the pan; the same is the case to a lesser degree throughout the boiling operations. Avequin found these incrustations from a copper pan, after destroying the organic matter they contained by a red heat, to consist of:

Basic sulphate of lime	92.43
Carbonate of lime	1.35
Silica	4.70
Phosphate of copper	1.41
	99.89

The formation of these crusts is obviously due to the application of lime as a clarifying material, basic phosphate of lime being precipitated and baked on from the alkaline liquid, together with insoluble compounds of lime, with organic matters. The deposition of this crust between the juice and the bottom of the pan frequently causes the saccharine juice to be overheated, the result of which is the burning of a portion of the sugar (production of caramel) as soon as the incrustation breaks up or loosens and the juice comes in contact with the hot metal.

The ordinary plan adopted for the removal of this panstone is simple, but injurious to the boiling pans. The empty pan is heated nearly to redness, when the crust peels off, in consequence of the greater expansion of the metal.

As a great improvement upon the old process just described, and copied from the refineries, the following is now being gradually adopted:

The clarified juice is conveyed to a series of mechanical filters, consisting of a number of sets of fine copper-wire sieves, each set being composed of four or more sieves, one above and fitting in to the other, becoming gradually finer in the mesh as they descend. The bottom sieve has a flannel bag attached to it, for the purpose of still further filtering the liquor, and abstracting the finer impurities and the feculent matter that has been expressed from the canes, and is floating in the liquid, which would, by reason of the small size of the particles, have escaped through the meshes in the wires. These filters are thus a combination of wire-sieves, with the ordinary bag-filters.

Sometimes the wire-filters are dispensed with, and flannel or bag-filters only used; and at others, some of each are employed. The object of these filters is to separate any dirt or fibrous matter that may have escaped with the juice from the clarifiers.

Figs. 83, 84, 85 represent these bag-filters. Fig. 83 is the plan, showing two of them. Fig. 84 is the elevation of the same two

FIG. 83.

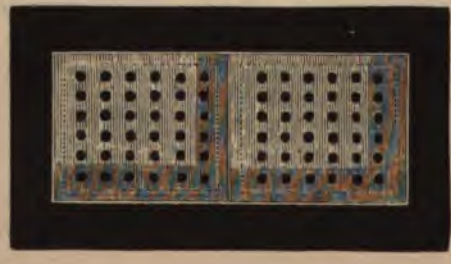


FIG. 84. FIG. 85.

filters. In one filter, the copper manhole *A* is removed to show the bags suspended.

Fig. 85 shows one of these filters in section. *B* is a copper cistern, that receives the juice, which afterwards passes through the filter bags *C*.

The combination of sieve-filters does not require a separate drawing, as the way in which the sieves fit into one another is sufficiently shown in the general elevation; the only difference in the way of suspending the filter-bag from the bottom sieve, from the way in which they are suspended in this drawing, being that, in the wire-filters, there is one large bag instead of several small ones.

The sugar-liquor, from which all the mechanical impurities have been separated, is next passed through animal charcoal or bone black. The charcoal filters in which this operation is conducted are large and slightly conical vessels, of either copper or iron, varying from 6 to 12 feet in height, and are furnished with a perforated false bottom, made for the convenience of removal, in several separate pieces, on which short iron supports are cast in order to produce a space between the false and main bottoms of

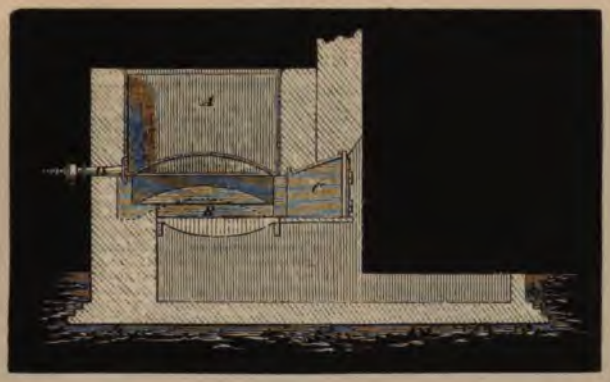
the filters. A filtering cloth or blanket is spread over these perforations, to prevent the filtered juice, in running through, from carrying any of the bone black with it; some, however, always accompanies the liquor at the commencement of the operation, which is consequently rejected, and again passed through the filters. The charcoal filters have sometimes open and sometimes closed tops; in the latter case (which is adopted for the purpose of keeping the sugar-liquor warm, and so causing it to run quicker through the charcoal), manholes in the side, at the top and bottom, are necessary, in order to fill and empty them. In filling these vessels, the first few inches of bone black should be pressed compactly down; after which it is piled lightly, but evenly, to within a short space of the top, which is left for the reception of the cane-juice. The object to be attained in these filters is the removal of all the vegetable colouring matter from the sugar-liquor, and any excess of lime that may have been accidentally added in the clarification, as well as some of the mineral salts, such as sulphate of lime, originally existing in the cane-juice.

About 5 tons of animal charcoal are consumed to every 100 tons of sugar made. The expense of reburning the used charcoal, so as to render it available for another operation, including the loss in the retorts, is about £2 per ton. The filtered sugar-liquor is now ready for evaporation; the whole of this evaporation might be conducted with some advantage in the vacuum-pan, but, for the sake of economy in the original cost of the apparatus, it is generally carried on in open vessels, till the juice attains a density of from 25° to 28° Beaumé; up to which point it receives but little injury, at the temperature requisite for its evaporation, under the pressure of the atmosphere. There are three methods of effecting this preliminary concentration:

1. By means of fires playing directly upon the bottoms of appropriate vessels containing the juice, as described above, or as shown in the vessels (Figs. 86 and 87) which represent open fire evaporators, and the way in which they are set in brickwork. These open evaporators are of very inferior efficiency to the two other methods described below, and are only improvements upon the common fire process, inasmuch as the juice, when at 25° or 27° Beaumé, is removed to the vacuum-pan, and it is at a density above that, that the cane-juice is most injured by the heat of the fire in the common process.

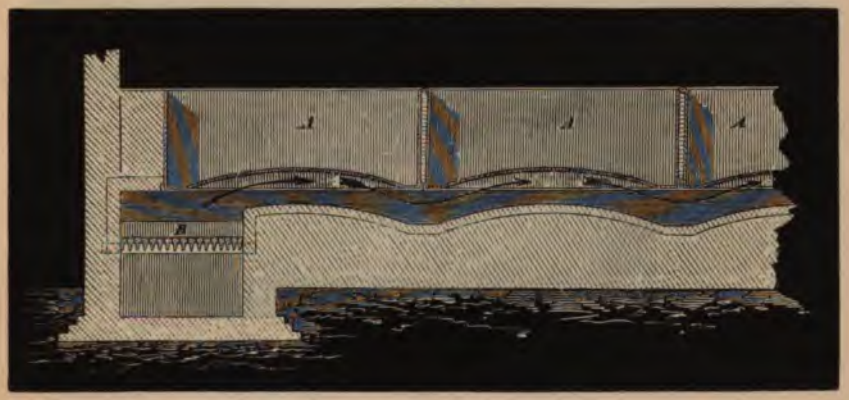
A are the evaporators made of sheet-iron, firmly rivetted.

FIG. 86.



B is the fire-place—the flame proceeding along the flues, in the direction of the arrows, to a chimney at the end of the range of evaporators.

FIG. 87.



C is the fire-door for stoking, and

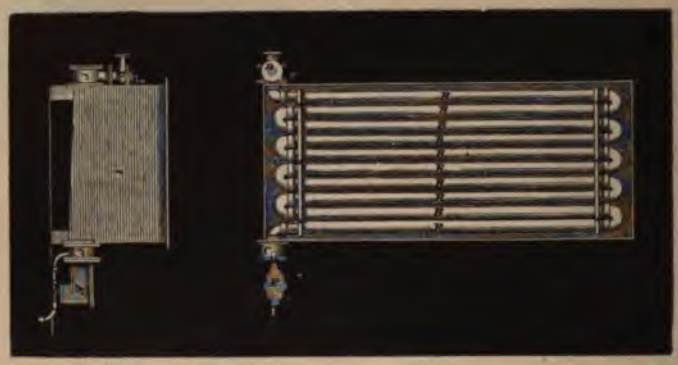
D is a pipe attached to each evaporator, supplied with a cock for running off the concentrated juice.

2. Another method is by the application of steam heat, the juice being admitted into large rectangular iron vessels, with steam pipes at the bottom, the extremities of which work through stuffing-boxes; thus enabling the men to raise the pipes on end out of the evaporators, and clean them thoroughly down.

Figs. 88 and 89 are drawings of the open steam evaporators, in which the cane-juice is concentrated to about 27° Beaumé, before going into the vacuum-pan. These are sometimes used in conjunc-

tion with the double-effect condensers, over which the cane-juice is first partially evaporated, when there is no second vacuum-pan;

FIG. 88.



but more generally these open steam evaporators are used when the condensers are not supplied.

FIG. 89.

Fig. 88 shows the cistern *A*, which is made of wrought-iron plates, rivetted together and painted. The copper pipes *B*, into which the steam is admitted, are seen at the bottom of the evaporating cistern; they are joined together by gun-metal bends. Each extremity of the series of pipes works through the stuffing-boxes *C*, by means of which they can be lifted up into the position shown in the longitudinal elevation, and be thoroughly cleaned down: this is very important, as if not properly washed after being used, some of the cane-juice may hang about them and become acid and infect the next charge. *D* is the valve through which the evaporators are supplied with steam. *E* is the condensed water-box.

It will be seen, in the transverse elevation, that these evapo-

FIG. 90.

rators are slightly tilted to one side; this is for the purpose of more completely running off the evaporated juice, a cock being provided for this purpose.

3. The third method is by applying the steam obtained from the evaporation of the cane-juice in the vacuum-pan to the concentration of the weak liquor, in an apparatus patented by M. Derosne, in France, and by Messrs. Pontifex and Wood, in England and the colonies. This apparatus is shown in Fig. 90, and consists of a series of straight copper pipes, one above the other, the ends of which are fixed into cast-iron boxes. The steam generated in the vacuum-pan, presently to be described, is admitted into the inside of these pipes, through the pipe *D*, over the outsides of which the weak juice to be evaporated is allowed to trickle from the serrated trough *B*, in a gentle shower, from one pipe to another,

collecting in the trough *C*, whence it passes to the next stage of the process.

The vapour from the vacuum-pan passing through the inside of the pipes, in the direction of the arrows, finally issues out through the pipe *E*, which is connected with a small air-pump. In proportion as the cane-juice, in its passage over the pipes, becomes more and more concentrated, and therefore more liable to injury from heat, in this apparatus, the heat is being proportionally diminished by the gradual condensation of the steam, which is considered a great advantage. The result is, that the steam in the inside of the pipes, parting with its latent heat to the juice on the outside, the one is evaporated whilst the other is condensed; thus enabling the vacuum-pan to do nearly twice as much work as it would otherwise perform. In this stage of the evaporation but little description is necessary, the only object to be attained in any of the three processes mentioned, being to concentrate the liquor as quickly, with as small a quantity of fuel, and as little injury to the sugar, as possible.

Having now arrived at that point in the evaporation of cane-juice, beyond which it is injudicious to proceed at the temperature necessary for boiling, under the pressure of the atmosphere, the partially concentrated juice is passed into the vacuum-pan, where the evaporation is completed. If, however, a very superior quality of sugar is required, the syrup, having been first slightly heated in a cistern for the purpose, is again passed through the charcoal-filters, before proceeding to the pan. The principle of the vacuum-pan is simply to remove the pressure of the atmosphere, to enable the juice to boil at a lower temperature. The instrument itself consists of a copper pan, surrounded on the outside with a cast-iron jacket, with a space between the two to admit of steam being introduced, in a similar way to that described in the clarifiers.

In the inside of the copper pan is a worm or coil of pipe, also of copper, through which a supply of steam is continually passing, the object being to obtain as much heating surface as possible. A copper dome is fixed on to the top of the copper and iron pans, by means of flanges, so as hermetically to close the whole apparatus. The steam generated in the vacuum-pan is removed, and the vacuum maintained either by a process commonly known as condensation, by injection, or by the patent condenser, already described. In the case of condensation by injection, or the common method of condensing the steam in a

steam-engine, the vapour from the vacuum-pan is admitted into a cast-iron cylinder, containing a perforated pipe, by means of which a shower of cold water is introduced into contact with the steam, thereby condensing it, and producing a partial vacuum. (A drawing of this apparatus is described under beetroot sugar.) This vacuum is perfected by means of a very powerful air-pump, which is necessary both to remove the water used in the condensation, and also to get rid of the large amount of air carried in with it; and as air is infinitely more difficult to remove than water, this proves a very serious objection to the method of condensation by injection. This objection is entirely avoided by using the patent condenser, as, by obviating the necessity of admitting water into contact with the steam, it prevents any air from entering into the pan.

Among the other advantages this process possesses over the common method of condensation are, that, besides a direct saving of from 40 to 50 per cent in fuel, it renders the vacuum-pan available in those places where it could not otherwise be used, in consequence of the scarcity of water, the quantity necessary for condensation by injection being very great. It also ensures a considerable saving, when steam-boilers are used, both in freight, cost of setting, and daily labour in stoking. No air-pumps being required for effecting the condensation of the steam, as on the old plan, the power required to work them is also saved. It has, however, been found advisable to attach a small air-pump to the patent condenser, principally for the purpose of more expeditiously removing the water formed by the condensation of the steam in the pipes, and also to remove any air that may be in the pan at the commencement of the day's work, or may be afterwards accidentally admitted. The French often work this condenser without any air-pump, but the vacuum in that case is never so perfect as it should be.

If water be substituted for cane-juice, as the condensing medium on the outside of the pipes, as was originally done at the first introduction of this apparatus, a great saving in its consumption will be effected; for as steam, at the ordinary pressure of the atmosphere, always contains 1212^0 of heat, 1000^0 of which are latent, and 212^0 sensible; and as water, under the same circumstances, can never be raised above 212^0 of sensible heat, it follows that the process which can convey away the latent, as well as the sensible heat, must be more effective than that which only conveys away

the sensible heat, in the proportion of 1212^0 to 212^0, or, in other words, if the steam from the pan be condensed by injection, the water for which must not be raised to the boiling point (or no vacuum would be produced), nearly six times as much water will be required to effect a proper condensation as would be necessary if the condensing medium could, as in the patent condenser, be converted into steam, without in any way injuring the vacuum in the pan.

This condenser has also been applied most advantageously to steam-engines, producing a vacuum varying, according to the state of the atmosphere, from 26 to 30½ inches of mercury, and, when attached to the high-pressure engines used in sugar manufactories, will be found to produce the following most important results:

1. The waste steam from the engine will evaporate the weak cane-juice in the same manner as the vapour from the vacuum-pan. 2. It saves and returns to the boilers the condensed water, which is hot and perfectly pure. And, 3. It converts a high-pressure engine into a condensing one, by the addition of a small air-pump; thus increasing its power, and decreasing the cost of the fuel in working it.

In these condensers much depends upon the regulation of the amount of surface to which the steam is exposed, upon its first issuing from the pan, and so arranging it, that, as the volume of steam diminishes by condensation, the condensing surface shall also be proportionally diminished. On this point the French have hitherto been foiled, as, instead of passing the steam, when in greatest volume, through several pipes at once, and gradually diminishing the number through which it passes, till it is sufficiently reduced in volume to traverse with ease through a single pipe, they oblige the whole volume of steam to pass *seriatim* through each separate pipe; thus to a certain extent choking up the entrance to the condenser, when the greatest amount of condensing power is required.

The two accompanying drawings (Figs. 91 and 92) represent the vacuum-pan and the mode of working the discharge-cocks. The following letters, where they occur in both drawings, answer for both. These are also shown, coloured, in Plates I. II. and III.

The vacuum-pan is composed of

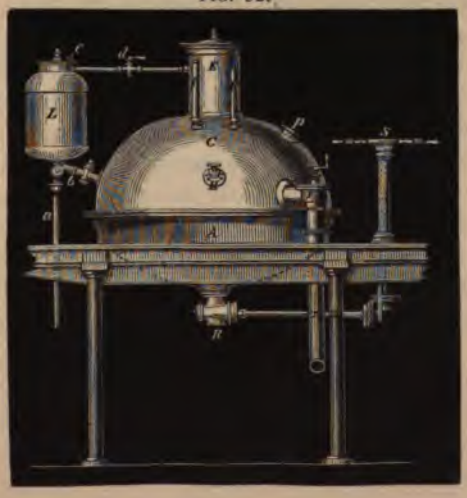
A the outside cast-iron pan or jacket.

B the inside copper or evaporating-pan.
C the copper dome, surmounting and secured by flanges to the

FIG. 91.

others. The way in which they are all fastened together is shown in Fig. 91.

FIG. 92.



D is the copper-worm, or coil of pipe, through which steam is passed. Steam also occupies the space between the pans *A* and *B*.

E is the manhole, with a moveable gun-metal top, hermetically ground into its collar. It is taken off when the pan requires repairs or cleansing.

F is the valve through which steam for the evaporation is supplied to the pan.

G is a smaller valve, through which steam is admitted into the interior of the pan, for cleansing.

H is the proof-stick, for abstracting a sample of the sugar during the progress of the evaporation, specially described further on.

I is a thermometer, for ascertaining the temperature at which the liquor in the pan is evaporating.

K is a barometer, or vacuum-guage, for ascertaining the amount of vacuum, or, in other words, the pressure existing in the pan.

L is the measure for regulating the quantity of juice admitted into the pan. It has a pipe and cock *a*, dipping into a cistern below, from whence the pan is supplied. *b* is the pipe and cock, conducting the measured juice into the pan. *c* is a glass gauge, encased in brass-work, for exhibiting the quantity of juice in the measure, in a similar way to the water-guage in a steam-boiler. *d* is a pipe and cock leading to the pan, through which the vacuum in the pan acts upon the juice in the cistern, and draws it up into the measure. When the measure is to be filled, the cocks *a* and *d* are opened, and the juice drawn up into the measure, as soon as it is sufficiently full these cocks are shut, and the cock *b* is opened; but as the cold liquor coming into the measure will have condensed any vapour admitted into it from the pan, when the cock *d* was opened, there will be a greater vacuum in the measure than in the pan, into which the juice will consequently not run till the pressure of the atmosphere is admitted into the measure, through the cock *e* in its cover, which is therefore opened, when the juice immediately runs into the pan. Mr. Pontifex has suggested the use of steam instead of atmospheric pressure to force the liquor into the pan.

M is an overflow vessel, for receiving any liquor that may accidentally boil over from the pan. When this occurs, it is indicated by the glass guage attached to it, and the juice is racked off through the cock at the bottom of the overflow vessel, or receiver, as it is called.

N is a small air-cock, in the arm-pipe of the pan, which conducts the vapour generated in the pan to the condenser.

There is a small peep-glass *p*, in the dome of the pan, with a corresponding one on the other side; so that, by looking through one, the other affords sufficient light to see how the sugar liquor in the pan is progressing.

The sugar is run out of the pan, as delineated in Fig. 91, by the gun-metal saucer *O*, which is hermetically ground to fit the socket *P*, which is attached to the pan. The saucer is raised or depressed by means of the long lever-handle *Q*.

In Fig. 92, a cock *R* is substituted for this saucer, and it has the advantage that it can be worked by the sugar-boiler, by means of the wheel and handles *S*, without his having to leave the vacuum-pan stage.

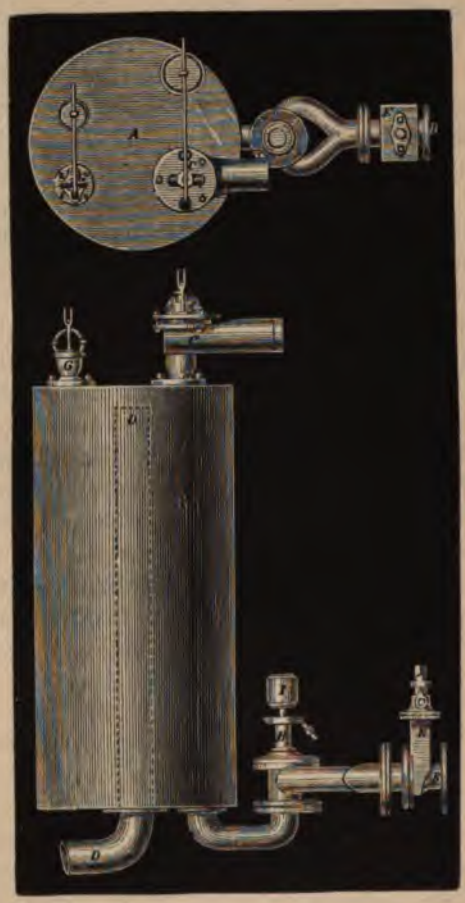
Besides the apparatus for maintaining a vacuum, the pan has attached to it a measure, regulated in its size by the contents of the pan, but generally containing about 35 gallons; this measure is provided with a gauge glass on the outside, and is for the purpose of regulating the quantity of juice admitted into the pan. A proof stick, for withdrawing a sample of sugar from the pan, without disturbing the vacuum, is also provided: this implement consists of a copper rod, with a receptacle at the end for receiving the sample of sugar, into the body of which it is dipped, by being passed down a pipe soldered on to the dome, and dipping below the surface of the liquor; thus preventing the admission of any air during the insertion or withdrawal of the proof-stick. This instrument is shown at p. 297, Fig. 91.

Fig. 93 is a drawing of an expansion vessel, or vessel to expand, and reduce the pressure of the steam to the proper point for use in the vacuum-pan. It consists of a large cylindrical plate-iron vessel *A*, into which the steam is admitted by the pipe *B*. There is a valve *C*, at the top of the vessel, loaded to the required pressure, through which the steam escapes as soon as the pressure in the vessel rises above that point. The expanded steam is then conducted away to the vacuum-pan, through the pipe *D*. *E* is a valve for opening or shutting the communication between the boilers and the expansion-vessel. *G* is a small safety and self-regulating valve.

This is the common method of expanding, but a considerable waste of steam attends it, as all above the required pressure has to escape, and is lost. Messrs. Pontifex and Wood have lately contrived a peculiar valve *H*, to obviate this defect.

In *H*, which is a hollow cylinder, is a solid piston, or plunger, loaded to the required amount by the weight *I*.

FIG. 93.



As soon as the pressure exceeds the counterbalancing weight, the piston, against the bottom of which the steam acts, rises and partially shuts a valve regulating the admission of the steam; when the pressure of steam is so reduced, that the power of the weight forces the piston down, the valve is again fully opened.

On commencing boiling in the pan, the syrup should be run in as quickly as possible, till the whole of the heating surface is covered, when the steam is turned on, and the evaporation conducted at a temperature of from 180° to 190° F. As soon as the

syrup begins to granulate or form crystals, the temperature is reduced to 160° F.; and finally, just before the evaporation is completed, and the sugar ready to be let down into the heater, it is further reduced to 145° F., that being the lowest temperature at which proof-sugar boils at 3 inches below a perfect vacuum. When the sugar-boiler ascertains, by withdrawing a sample of the syrup by means of the proof-stick, and drawing it out against the light, between his finger and thumb, that the crystals are in a sufficiently forward state for his purpose, he adds another measure-full to that already in the pan, and the same process is repeated till the whole charge has been admitted. At each successive charge, the crystals continue increasing in size, to the end of the operation, those first formed acting as nuclei. A skip, as it is technically called, or a panful of the concentrated sugar, should have been made in from an hour and a quarter to two or two hours and a half from the commencement of boiling. If a fine-grained sugar be required, greater quantities of syrup are admitted at each charge of the measure, and *vice versâ*. The concentrated juice, or proof-sugar, which is at a temperature of 145° F., is then let down, through a cock or valve in the bottom of the pan, into the heater. The sugar-liquor consists, at this stage of the process, of a large number of small crystals, floating in a medium of syrup.

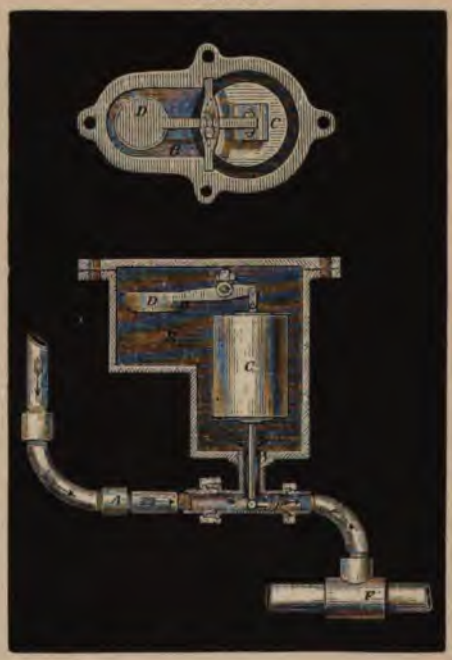
The heater is an instrument of exactly the same description as the clarifier, but larger, and generally has no light-course on the top. It consists of a copper pan, with an outside cast-iron jacket, with a space between the two for the admission of steam. In common with the vacuum-pan and clarifiers, the heater has attached to it a means of allowing the water, formed by the condensation of the steam to escape, without the loss of any of the steam. For effecting this purpose, a condense-box is employed; it consists of a cast-iron box, with a pipe at the bottom, in which is a valve attached to a float-stone. As soon as any water enters the box, the float-stone rises, opens the valve, and allows the water to escape; when the float-stone again falls, the valve is closed; thus preventing the escape of the steam admitted into the box with the condensed water.

Fig. 94 shows the plan, and the sectional elevation of a condensed water-box.

The condensed water, together with some of the steam with which the clarifier or vacuum-pan, or whatever vessel it may have

been that has been supplied, passes down the pipe *A*, in the direction of the arrows, into the interior of the cast-iron box *B*.

FIG. 94.



The rise of water in the box then causes the float-stone *C* (the weight of which is nearly counterbalanced by the weight *D*) to rise, thereby opening the valve *E*, and allowing the water to escape through the pipe *F*, which communicates with the whole range of condense-boxes. As soon as the water has escaped from the box, the float falls, and shuts the valve, thus preventing any loss of steam.

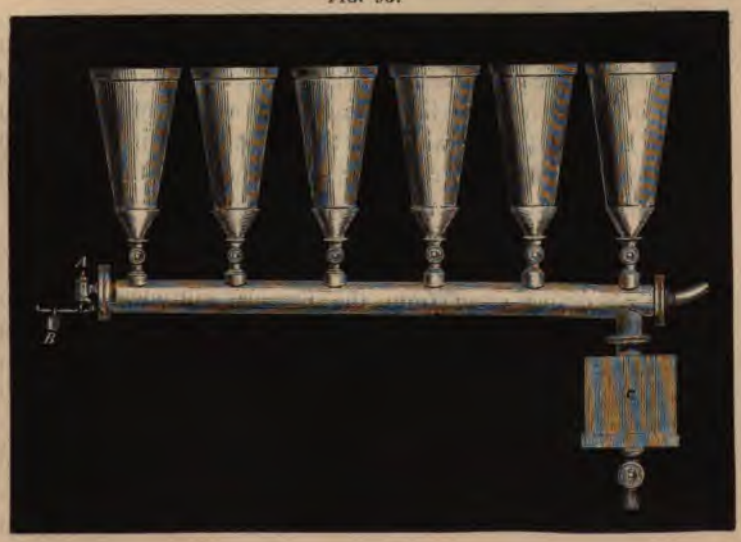
The object to be attained in the heater is to raise the sugar to a temperature of 180°, which has been found by practice to be the point best adapted for hardening and completing the formation of the crystals; during which process the sugar is constantly stirred with wooden oars, to promote its granulation. The sugar is then either ladled, or run out through a cock in the bottom of the heater, into a bucket, from whence it is poured into moulds or small cones, with a hole at the bottom of each, plugged up with a piece of paper. These plugs are removed the morning after the moulds have been filled, and the sugar is then subjected to a

process of liquoring for three or four days; during which time it should be kept at a temperature of about 100°.

Liquoring consists in pouring a small quantity of pure sugar and water on the top of the sugar in the moulds, through which it percolates, carrying with it the small proportion of colouring matter not previously removed. The drainings are collected in pots, placed under and supporting the moulds, and are boiled down with the other refuse of the sugar-house, to form an inferior quality of sugar. Instead of a separate pot for each mould, gutters, communicating with a row of moulds, may be advantageously substituted; or, still better, a false floor of thin sheet-copper, sloping every way towards the centre, may be constructed under the main floor, the drainings being conducted by a copper pipe to a cistern, preparatory to their being again operated upon. The draining of the moulds is sometimes expedited by connecting their nozzles with a pipe communicating with an air-pump, the vacuum created drawing the syrup through the body of the sugar. The principle of Hagues' pneumatic apparatus is identical with this, but in that case the sugar is placed in a large box, with a perforated bottom, and not in moulds. The objection to both plans is the liability of some of the sugar being drawn through the perforations with the syrup, by the force of the pumps.

Fig. 95 illustrates the method adopted by Messrs. Pontifex and

FIG. 95.



Wood for connecting the moulds, in which the sugar is being cured, with an air-pump, to hasten this process. The ends of the moulds are ground hermetically into the sockets of the cocks, shown underneath each of them, so that they can be readily removed. The large pipe below, and common to all the moulds, is connected by means of the smaller continuation of it, to the air-pump of the engine, and is furnished with a valve for ascertaining the pressure; which is done by moving the weight *B* along the graduated beam, on which it is suspended. The drainings traverse the larger pipe, and are collected in the cistern *C*, from whence they are conveyed back to the vacuum-pan, or elsewhere at pleasure.

This sketch merely shows the principle on which the process is worked. There are several modifications of the apparatus now in use. The old plan of each mould standing in its separate earthenware pot, is still in general use, notwithstanding the expense of so many pots, and the liability of fermentation commencing in the house, from some of these pots not being properly washed out. The manner in which fermentation (or smear, as it is technically called) spreads through a whole establishment with astonishing rapidity, is very curious; and, when once established, it is extremely difficult to eradicate. A sugar refiner in this country had twice to work up his whole stock, at an enormous expense, before he could get rid of this fermentation which had arisen from the above causes.

When the sugar is sufficiently drained in the moulds, it is taken out in the shape of loaves, which are trimmed and afterwards placed in a stove, where they are kept at a temperature of from 130° to 140° F., till the whole of the moisture in them has been evaporated; they are then ready for sale. The sugar thus obtained will be half the weight of that let down into the heater from the vacuum-pan, the remainder having passed off as moisture, or been returned to the pan as drainings. A very small proportion of the syrup that drains away from the moulds will always remain uncrystallizable, in consequence of its having accumulated to itself all the impurities not entirely removed in the various processes the sugar has undergone; it will exist as treacle. If the operations here described have been properly conducted, the resulting sugar will be almost, if not quite, equal to refined sugar; in fact, there can be no possible reason why perfectly pure white sugar should not be made from the canes in one operation,

the refiners having to labour under the great disadvantage of working upon a material that has been very considerably deteriorated in quality by previous mismanagement; whereas the colonial sugar manufacturer has to operate upon an article which has been shown by M. Péligot to contain only 1.5 per cent of impurities. It is, however, against the interest of the manufacturer in our colonies to make a good quality of sugar, as there is in this country a very heavy, amounting to a prohibitive, duty on sugar, above a certain standard; thus giving a premium to slovenly and bad works: the consequence of which is, that whilst in our own possessions but very few improvements upon the old and barbarous method of making sugar are progressing, in Java, and Cuba, and elsewhere, the manufacturers are making the most rapid strides, giving almost unlimited orders for the most improved machinery, and engaging the most skilled and best available men for superintending the erection of machinery and working the estates.

It has been found by actual practice, that the improved machinery here described will effect a saving in the manufacture of sugar over the old and wasteful process, of from 30 to 40 per cent in quantity, the market value of the whole of which has been increased by from five to ten shillings per cwt. The advantages of boiling *in vacuo* are such as must compel its adoption, wherever sugar is made.

The necessity admitted by all enlightened agriculturists of restoring to the ground the most appropriate food for its future crops, has been proved to hold good with the sugar-cane, as with wheat and other products. By the use of trash or the refuse canes, and some little guano for manure, the yield of the cane, in several parts of the West Indies, has been doubled and trebled, as much as 4 tons of sugar per acre having been made, even under the present wasteful system of manufacture. This valuable manure is rendered available by the use of the vacuum-pan, as it is not then necessary for fuel.

To the advantages already enumerated, an immense increase in the quality and quantity of the sugar may be added; and the large amount of saccharine matter saved, that is now always pumped out of the hold of the vessel at sea, during the transport of the sugar to this country, in consequence of the quantity of molasses that is mixed with the sugar continually deliquescing and finding its way out of the casks, washing the sugar away at the same time.

It is not necessary to remind the reader that improvements in various manufactures have been the means of raising them from a state of depression and insignificance, to great prosperity and national importance, and there can be no reason why the manufacture of sugar should be excepted from the advantages that science holds out, and which experience has proved can be applied so beneficially.

Estates in the West Indies, that are now being cultivated at a heavy loss, might, if improvement were introduced, return to the enterprising and skilful cultivator a large profit, and to the capitalist a much more advantageous return than can be obtained by any other use of capital.

At the end of the volume will be found a description of the whole arrangement of machinery necessary to the manufacture of refined or pure sugar direct from the cane juice, with four illustrative plates of the manner in which the process has been carried out in the island of Cuba.

c.) *Crystallization.*

Upon the plan established by ancient usage, the boiled syrup was drawn off into coolers, and from thence placed at once in the casks, to crystallize in the best manner it could. More recently, special crystallizing pans have been introduced with great advantage.

The operation consists in conducting the concentrated juice into large, flat, cooling vessels, of 30 to 40 cubic feet capacity. These are constructed of wood, with very thick sides, that the cooling process may proceed slowly, and the grain of the sugar not be too small. At the expiration of twenty-four hours, when the syrup is no longer hot, but only luke-warm, and the granular crystallization (granulation) peculiar to raw sugar, has been effected, the mass is stirred with iron rods, in order to produce a uniform temperature and consistence, and is then scooped into wooden moulds constructed of deals. The uncrystallizable portion drops through the crevices and the bottom of the mould, or through holes bored expressly for the purpose, which at first are closed with stoppers of sugar-cane, into receivers below, above which the moulds are arranged. These receivers are very large, and capable of holding from 15 to 20,000 liters or more (= 3300 to 4400 gallons).

In two or three weeks, under favourable conditions, or in five or

six weeks, when the mass is mucilaginous, and the grain very small, the molasses separate as far as they can, but the separation is never very complete. The moist brown or brownish crystalline flour remains in the mould, and varies very much in quality, according to the greater or less degree of care expended in the preparation, and according to the nature of the original cane. It is called *raw sugar.*

Raw sugar.—The most important varieties of raw sugar which occur in European commerce are—

1. The *West Indian* — Jamaica, Martinique, Guadaloupe, St. Croix, St. Thomas, Domingo, and Havannah.
2. The *American*—Rio Janeiro, Bahia.
3. The *East Indian*—Mauritius, Manilla, Java, and Canton.

Raw sugar is chiefly exported in cases; other kinds, like that of Jamaica, Domingo, and St. Croix, in hogsheads; the Manilla and Mauritius sugar, in double sacks, plaited or woven from the leaves of reeds. The quality of this colonial produce varies, in all degrees, from the white, almost equal to loaf-sugar (white Havannah) to the dark-brown, moist, sticky, and smeary character of the worst varieties. The white colour and dry state are the exceptions, the ordinary raw article being moist and brown. The more coarsely granular, the harder, drier, and whiter the sugar, the greater is its value, and the better is it adapted to bear carriage.*

In the cisterns, where the syrup, dropping from the moulds, collects, and becomes cooled to the temperature of the surrounding air, an additional portion of sugar separates, the grain of which

* Pure dry crystals of cane-sugar are not affected by exposure to the air, even after a very long time; they possess, on the contrary, a stability which is of the utmost importance to the commercial value of the purified or refined sugar. Similar qualities cannot be expected in raw sugar, which is only a crystalline flour of pure sugar, moistened throughout with molasses, which latter often amounts to $\frac{1}{3}$rd of its weight, and indeed often to more than the crystalline flour can retain. Molasses consequently flows away from raw sugar as soon as it finds an opportunity. During the passage to Europe this constantly occurs, as it attracts moisture from the damp air of the vessel, and becomes more limpid, and escapes, during the whole voyage, from the crevices in the casks; the loss by leakage is consequently very considerable. Dutrone states, that of the 120 millions of pounds of sugar annually exported from Domingo to France, only 96 millions arrive at their destination, and that 20 per cent are therefore lost. The amount of leakage from the English colonies is at least 12 per cent, and is consequently calculated at 27,000 tons annually.

resembles that of fine sand, and forms layers on the bottom, of several inches in thickness. This product, naturally of a very inferior character, is known by a distinct name (*fond de cisterne*), and its quantity increases with the temperature at which the sugar is placed in the moulds; on an average, it amounts to 10 per cent of the raw sugar. The moist and smeary character, the admixture of various salts, gelatinous silica, and mucus (gum), are easily explained, when it is remembered that it is deposited from the refuse syrup, or the mother-liquor of the first crop of crystals. Avequin obtained from 10,000 parts of this sugar:

Silica	32.53	parts.
Phosphate of lime	43.75	„
Mucus or gum	48.65	„
Colouring matter precipitated with the phosphate of lime	2.28	„
Sulphate of potash	50.10	„
Chloride of potassium	67.41	„
Acetate of potash	65.57	„
Acetate of lime	12.30	„
	322.59	

It is obvious from this analysis that the deposition of phosphate of lime extends through the whole range of operations in the production of raw sugar, and that the silica dissolved in the juice is only deposited when the juice has attained a high degree of concentration.

Produce in raw sugar.—The process first described above as the older process, is that still commonly pursued in the American West Indies, and although an improvement upon the still older methods, particularly upon the East Indian, is nevertheless extremely crude, and according to what is known respecting the characters of sugar, is not well adapted to the objects in view. On an average, not more than from 60 to 80 parts of raw sugar, and 25 to 30 parts of molasses, are obtained from 1000 parts of the sugar-cane; while the same quantity should yield, according to analysis, from 180 to 200 parts of crystallizable sugar. Far more than the half is therefore lost, partly from the defective methods of pressing, and partly from the inefficiency of the other parts of the process.

Two experiments of Dupuy, the one conducted with 63,000 kilos., the other with 17,750 kilos. of sugar-cane, showed it to contain the following quantities of the different products, in 1000 parts:

	I.	II.
Raw sugar	79	73
Molasses	30	27
Expressed cane (Bagass)	386	395
Water	505	505
	1000	1000

In other words, of the 180 to 200 parts of crystallizable sugar, in the 1000 parts of sugar-cane, there are

obtained	as raw sugar	73 to 79 parts.
	as molasses	18 „ 20 „
and there are at least wasted	in bagass	28 „ 33 „
	in the process of manufacture	61 „ 48 „

Salts contained in raw sugar.—All raw sugar leaves some insoluble matters, when dissolved, consisting of the same substances, which are precipitated during its purification as panstone, or in the collecting cisterns. According to Avequin, these admixtures, which are nothing but mechanically attached scum and flocculæ, consist of the following ingredients, in 10,000 parts:

Silica	27.65 parts.
Phosphate of lime	43.43 „
Carbonate of lime	58.06 „
Organic matters	2.52 „
Sulphate of potash	19.42 „
Chloride of potassium	26.13 „
Acetate of potash	25.41 „
Acetate of lime	17.26 „

Molasses.—In a plantation of Louisiana, which produces annually 500 hogsheads of sugar, it is calculated (as a six-yearly average) for every 1000 lbs. of perfect raw sugar, that 55 gallons, or 208 liters of molasses, of 40° B., or 1.376 spec. grav., are obtained, which weigh 572 lbs., and correspond to 57 per cent.

In Guadaloupe, Bourbon and Martinique, the quantity of molasses often does not exceed 40 gallons to the same amount of sugar.

Chemical nature.—Molasses consists of a concentrated solution of the products of the conversion of raw sugar into caramel and other products of decomposition, which however compose the smallest portion of the entire mass; it contains also those salts which are not precipitated by lime, and have accumulated; and very probably compounds of sugar with the salts; and, lastly, a kind of gum or mucus. The solution of all these substances is necessarily saturated with raw sugar. In a practical point of view, therefore, without reference to the foreign ingredients, molasses is a solution containing sugar in two modifications, in the crystallizable and uncrystallizable or mucilaginous condition. Chemistry leaves us quite in the dark respecting the nature of the latter substance (compare p. 247), but experience proves that a very small addition of saline matter hinders the crystallization of sugar, and therefore authorizes us to suppose that the presence of these substances form the chief peculiarity in the molasses. In the following analyses (optic-araeometrical), by Ventzke, no notice is taken of the salts. He found in

	Green bastard syrup.	Ordinary brown Manilla.
Cane sugar	47.9	67.7
Sugar-syrup	30.9	26.4
Water	21.3	6.0
	100.1	100.1

Avequin, on the contrary, obtained from 10,000 gr. of molasses, collected as a secondary product from the raw sugar of Lousiana:

Acetate of potash	208.31
Chloride of potassium	113.63
Sulphate of potash	84.46
Phosphate of lime (acid)	51.01
Silica	22.85
Acetate of lime	15.18
Phosphate of copper	0.21
Gum	66.28
Purified sugar	7.76
Water and uncrystallizable sugar	9430.31
	10,000.00

A comparative analysis of the ashes of raw sugar, and of the molasses accompanying it, the origin of which is unknown, has been furnished by Richardson:

	Brown raw sugar afforded 1.33 per cent of ash, consisting of:	Molasses from the same afforded 3.6 of ash, consisting of:
Potash	19.42	36.23
Lime	14.67	12.72
Magnesia	10.72	11.14
Oxide of iron	6.55	2.62
Oxide of copper	0.71	trace
Oxide of manganese	trace	trace
Chloride of potassium	8.03	1.58
Chloride of sodium	15.46	25.87
Sulphuric acid	10.85	7.91
Silica	13.59	1.93
	100.00	100.00

The same constituents are found here again which Stenhouse (p. 256) detected in the ash of the sugar-cane, but naturally in other proportions. The lime has been increased by the addition of milk of lime in the clarification; the oxides of the metals composing the vessels are now found in the ashes, while the phosphoric acid has been entirely separated, remaining in the pan-stone. The presence of these salts explains not only the difficulty attending the crystallization of molasses, but likewise its purging action and power of absorbing moisture from the air which it communicates to the raw sugar. Many kinds of raw sugar melt into syrup when exposed to the atmosphere.

In the fresh state molasses present a sticky dense liquid of a brown-red colour, and such a decidedly saccharine taste, that the salts are completely masked. Notwithstanding its high state of concentration, it is not very stable at elevated temperatures, but exhibits a great tendency to undergo the vinous and acetous fermentations. The molasses of the colonies, obtained from raw cane-sugar, are essentially distinct from the molasses of the beet-root sugar factories (see below), the latter being more completely exhausted mother-liquors and containing consequently less sugar and more foreign ingredients. The former are much employed

in the colonies and in Europe as an inferior kind of liquid sugar, a use to which the beetroot molasses could not be applied. The greater part, however, is consumed in the production of rum, and no additional quantity of sugar is ever extracted from them.

Proposed improvements.—The enormous loss and palpable imperfections of the old sugar process, which modern science and the European production of beetroot sugar have clearly proved, could not long remain generally known without affording a powerful stimulant towards the improvement of the colonial manufacture. The improvements as yet carried out or proposed, have chiefly been borrowed from the beetroot sugar manufactories, and carried from thence to the colonies.

The loss occasioned by an imperfect process of crushing or pressing was the first to excite attention. And in addition to the improved machinery described above, it has been proposed by some to soften the pressed cane in warm water, and to pass it a second time through the rollers; one-fifth more sugar is said to be thus obtainable. Payen recommends, that between the first and second crushing process the cane should be exposed to a current of steam with the same object in view. The elevated temperature of this current would obviate the possibility of fermentation being set up.

Other improvements refer to the boiling process. In place of the original deep pans, shallow pans arranged in terraces one above the other have been substituted with advantage. At a later period the application of steam heat was introduced in conjunction with the evaporation *in vacuo* and charcoal filters, as already described. Engine manufactories, like that of Derosne and Decail, in Paris and Brussels; and Pontifex, in London; construct complete systems of apparatus for shipment to the colonies. Machinery of this kind has been introduced chiefly into the French colonies, and also by the Dutch Government into Java with decided advantage.

All these improvements demand a more than usual command of capital, and can only be introduced where the proprietors of plantations, either have that at command, or can obtain it by association. The fundamental remodelling of the colonial sugar process for the better cannot be forced into existence by improved technical and mechanical contrivance, but must take its rise in the improved agricultural system and arrangements of the sugar-growing countries.

Another idea must not be here passed over, that of sending the sugar cane in a dried state (of about the dryness of beet, according to Schutzenbach) from the colonies to Europe, where the juice could then be extracted. The entire process of manufacture would thus be taken from the colonies with their imperfect machinery, &c. The sugar-cane may be dried with care without decomposing the sugar, and contains in that state between 60 and 70 per cent of crystallizable sugar. The complete desiccation supposes the cane to have been previously cut into pieces, and in this state the sugar in the cane undergoes such a modification, that in the course of weeks or months only half the amount of crystallizable sugar can be obtained from it. Besides this, the drying requires very extensive arrangements and more careful management than is to be expected from the negroes, so that even with European aid not more than 50 per cent of sugar can be expected. One half the weight of the dry cane has therefore to pay carriage without profit, and this is sufficient under the present systems of tarif to render the undertaking impracticable.

It would be still more hazardous to export the boiled juice, instead of raw sugar, as Ure has proposed, subject as it would be to all the consequences of injudicious treatment.

B. SUGAR REFINING.

Preliminary remarks.—We have now to consider the processes for the purification of the raw sugar produced in the colonies. The facts already adduced respecting the nature of this product afford sufficient evidence for the necessity of its purification whenever a purer taste and better appearance are requisite. All the processes employed in the purification of raw sugar, have for their object the removal of the colouring matter and the communicating a pure taste to the crude material, or in other words the separating the molasses as much as possible from the crystallizable sugar.

The division of labour in the production of raw sugar from the cane is of essential service, as it leaves the refining process to others with whose means (mechanical and pecuniary) the owners of plantations could in no way compete; it however has this disadvantage, that the entire amount of raw sugar has to be redissolved in water, which again must be removed by evaporation, during which process the sugar is again subjected to the chances

of decomposition connected with the boiling, and which inevitably destroy a certain quantity of crystallizable sugar. It cannot, on the other hand, be denied, that much less loss of material has been experienced in the refineries, since the improved methods and apparatus of the beetroot factories have been introduced into the process for refining cane-sugar. Formerly no other purifying material was known excepting the animal albumen contained in ox-blood, with which a new inducing cause to decomposition was introduced into the mass of sugar, and at the same time so few rational rules or directions were laid down, that the success of the operations depended mainly upon the ability and aptness of the workman.

Since the introduction of animal charcoal and steam heat into the refineries the result is comparatively sure, as far at least as can be attained by those improvements. It would be more complete if the refinery was established upon a safer groundwork than the plantation culture, which affords a raw material of ever-changing quality. The mere inspection and empirical signs are but very deceptive means of estimating the real value of raw sugar, in order to determine the process for its purification accordingly. Unfortunately science is not in a condition to supply the practical man with a sure and easily applied test for the amount of pure crystallizable sugar in raw cane-sugar, if the recently invented optical test cannot be considered such, and upon the applicability of which experience has still to decide. All that can be done at present in that direction is confined to the discovery of the relative amount of colouring matters, by experiments with animal charcoal on a small scale.

It will be obvious from this, why the profit of the refiner depends more upon an accurate knowledge of trade, or in other words, upon good practical experience in selecting the raw commercial article than upon the technical management of the manufacture.

Every step towards the production of a better quality of raw sugar is a boon to the refiner. This is the fundamental principle upon which in the first instance all the endeavours to improve the culture in the plantations must be directed. The prospective, but far distant aim, which must not be lost sight of, is the production of refined sugar at once from the juice without any of the intermediate steps.

a.) The melting.

The emptying the cases or hogsheads, for which purpose they are inverted over a clean smooth floor, is difficult of execution in some cases, as a quantity of sugar, too large to be wasted, adheres tenaciously to the staves or sides. The quantity that adheres is greater the more sticky the sugar, and it can be removed with less trouble and loss of time in the manner proposed by Beguet than by scraping it out. The hogshead is inverted over an arched copper surface in the form of a flat inverted boiler. Through the centre of the arch a steam pipe is introduced, and the edge is turned up so as to form a channel. When steam is admitted into the hogshead for a few minutes it condenses on the sides, and becomes saturated with sugar. This solution collects in the channel, and is allowed to flow into the steam pan, while the sugar is passed through a sieve to remove the lumps which would unnecessarily retard solution. A sufficient quantity of water is now added to the melting pan to make up about 30 per cent with that from the hogshead, and steam heat is applied not to produce boiling, but to dissolve the sugar in as short a time as possible. The formation of this concentrated solution, which is the first operation in the refinery, is called the *melting*. The melted sugar is allowed to flow immediately into the clarifying pan, while the melting pan is supplied directly with a fresh charge, so that one melting pan or blow-up cistern is generally sufficient for a large refinery.

The accompanying sketch (Fig. 96) represents a 'blow-up' cistern as used in some sugar refineries; the raw sugar is placed in it, mixed with a proportion of water to bring it, when dissolved, to a gravity of 26^0 to 27^0 Beaume, and steam blown into the liquor through the perforation in the single coil of pipe that lies at the bottom of the cistern. Whilst being dissolved, bullocks' blood and lime water are added to clarify it, and neutralize the acid.

A. The blowing-up cistern.

B. The steam main.

C. The steam valve.

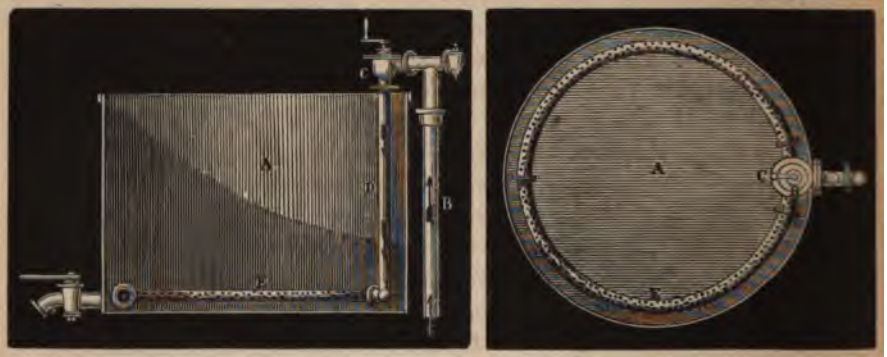
D. The descending pipe to coil *E.*

E. The coil of perforated pipe lying on the bottom of the cistern.

Messrs. Pontifex and Wood have lately introduced into the refineries with advantage a different shaped heater to the common hemispherical one. It is oblong, with a hemispherical bottom,

a shaft passes the whole length of the heater provided with arms, the shaft is driven by machinery, and the arms keep it thoroughly stirred, thus doing away with the two or three men ordinarily required to stir it; the heater can also be made larger by this plan, and thus less manual labour answers the purpose.

FIG. 96.



b.) The clarification; first and second filtration.

The nature of raw sugar necessarily implies that a clear solution cannot be obtained. The troubled appearance is due to minute particles held in mechanical suspension, which have remained attached to the sugar from the former process of clarification, and have been augmented in number by others in the process of packing. The former are so very fine and minute that they pass through all sieves and filtering apparatus. This is the very cogent reason why ox-blood cannot be altogether dispensed with, although from its great proneness to decomposition the sugar is placed in some jeopardy by its presence. By the coagulation of the albumen in the blood the mechanical impurities are collected into large connected flocks, and their separation is thus so facilitated in strainers, and so perfect that it would be difficult to substitute any other agent that would so effectually perform the same function. As however it is injudicious to add more blood than is absolutely requisite, only about ½ per cent of the raw sugar is employed, and its action is assisted by the addition of 3, 4 or 6 per cent of ground

animal charcoal. Much depends upon the uniform admixture of the albumen throughout the solution, and the blood is consequently first mixed with a small quantity of the saccharine liquid, which is then stirred into the remainder in the pan, the temperature of which must of course be kept at first under that at which albumen coagulates (70° C.=168° F.) This temperature must, however, only last for some minutes, that the blood may not have time to decompose, or exert any prejudicial action; the steam is then allowed full access into the pipes, in order to bring the sugar as rapidly as possible to the point of ebullition. The albumen is thrown up to the surface with the charcoal and insoluble substances, as a thick, compact scum, perfectly distinct from the clear liquid below, which at the same time is somewhat decolourized by the charcoal. When the coagulation is finished the liquid is passed without delay through a Taylor's filter.

Coated with albumen the suspended impurities are incapable of passing even through a very coarse filter, but in the course of the subsequent operations they would be again separated, and stop up the decolourizing filters, or pass through with the syrup. For this reason it is necessary to employ a Taylor's filter; and sometimes it is preferable to filter from the external to the inner surface, as the filters can then be more easily cleaned, and last longer. In this case a basket work must be placed in the interior of each bag to keep the sides from collapsing. The filtration through these bags is so rapid, that the ordinary charge of 7 cwts. of sugar in the melting pan can be passed through in from fifteen to twenty minutes. The filtered liquid is first collected in cisterns, from whence it is conducted to the Dumont's carbon filters for discolourization. When these are in proper condition they should discolourize a quantity of syrup which contains four times as much sugar as there is charcoal in the filter. The filtration of that quantity requires from fifteen to twenty hours. The syrup that has passed through, technically called *the liquor*, is collected in another reservoir which supplies the boiler.

c.) *The boiling.*

Boiling over an open fire is a practice that has been now almost universally abandoned, and is replaced by pans heated by steam, and generally by vacuum pans. The pans described below are the

[illegible]

[illegible]

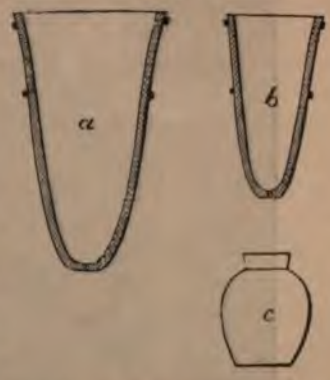
[illegible]

and the rapidity of the crystallization, must be modified accordingly. It also deserves special notice, that the high state of concentration of the syrup does not entirely preserve the sugar from the action of the air and its consequences, and that it is changed in proportion to the time spent in crystallizing and draining, during which operations it is exposed to the hot air of the refinery.

The irregular conglomeration of crystals which must be produced in the moulds, requires that the liquor should be poured into them at a certain temperature, and in the state in which crystals have already begun to form.

The liquor generally leaves the vacuum-pan at much too low a temperature, and requires to be heated up by steam to the proper point in a vessel with a false bottom. In the open pans it acquires too high a temperature, and must be cooled, an operation which is effected in cooling vessels capable of holding the entire quantity of liquor boiled in a day. While the temperature is falling in these, crystals often appear, which are small when the liquor is impure, and form with difficulty; but with pure liquor, have a tendency to be large, and form easily. As the grain must not exceed a certain size, the formation of crystals of too great dimensions is prevented by stirring, and this operation is repeated three separate times. When the cooling has been carried to a certain fixed temperature, the syrup is poured into the moulds. To facilitate the separation of the mother-liquor from the crystals, these moulds have always been constructed in the form of a funnel or sugar-loaf (Fig. 97), at the apex of which is a hole, and this, in the first instance, is closed up.

FIG. 97.



The larger the bulk of a crystallizing liquid, the slower it cools, and the more regular the crystallization, and *vice versâ*. For difficultly-crystallizable bad syrups, large moulds, called *bastard moulds*, *a*, are employed with the better kinds, which are inclined to afford too large a grain, smaller moulds are used. The moulds were formerly universally constructed of porous clay, and were not glazed; the porous sides,

however, absorb syrup, and give rise to trouble and labour in cleansing; iron moulds have consequently been substituted of late years, which are coated internally with a proper varnish, or with a glaze; cast-iron moulds are also in use, and are painted internally with white-lead paint.

In every case, the *thoroughly-cleaned* moulds are arranged in rows in the crystallizing rooms, either supported directly upon the treacle-jars *c* (Fig. 97), or upon wooden supports, under which the pots are placed. They are then filled with syrup, by means of scoops, from the coolers, in which the liquor has been stirred, in order to diffuse the crystalline particles that may have formed, equally through the liquid; and the filling is conducted in such a manner, that no mould is filled at once, but receives a portion of the sugar from all the layers of liquid in the cooler. The moulds are often filled on the lowest floors of the factory, and require to be raised to the upper floors, requiring much manual labour.

The accompanying drawings of a mould-carrier or hoist sufficiently explain themselves, and do not require a minute description. The apparatus passes up through the house, from the top to the bottom;

FIG. 98.

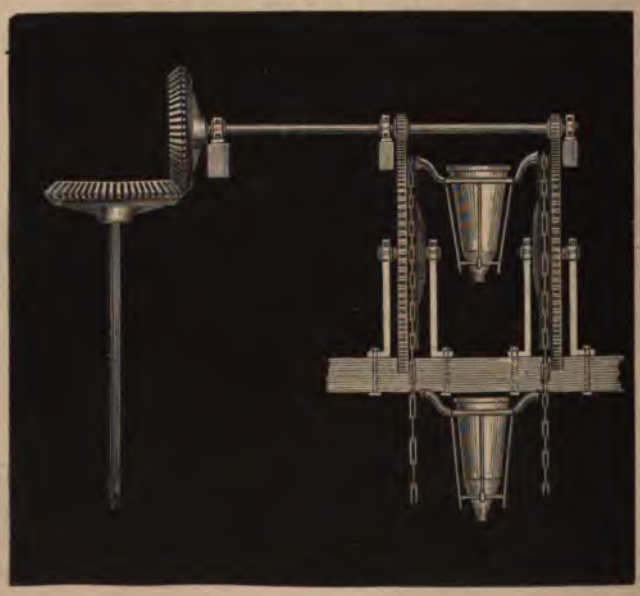


FIG. 99.

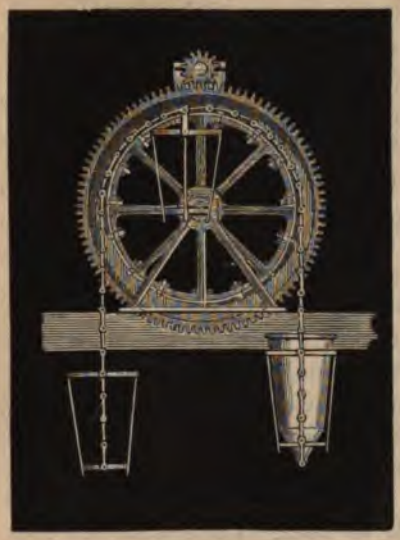
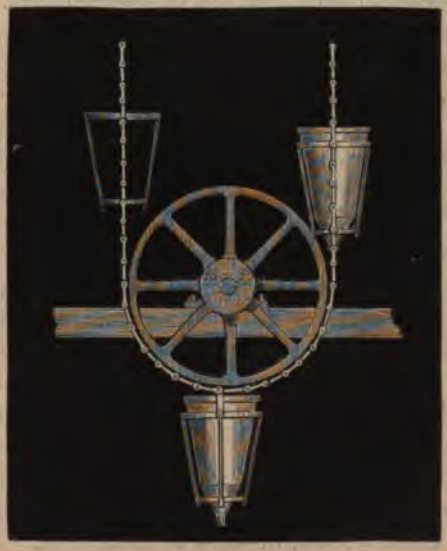


FIG. 100.

FIG. 101.



so that, if moulds are required to be raised from the ground to any intermediate floor, a man stands by the opening, and withdraws the mould from the cage in which it is contained, as it is about to

pass him. Some of these cages are shown empty, and some with the moulds in them. The old mould-hoist, when any was used at all, was very dangerous, as if the man above omitted to withdraw the mould as it passed him, on turning the top point, the mould was ejected from the cage on the heads of the men below, no provision being made for keeping the cages always in an upright position. The cages are made the full size for the largest description of moulds; and if smaller ones are to be lifted, rings of corresponding sizes are provided, to drop over the top and bottom of the cage, and thus hold the mould firm.

As is the case in every crystallization, so that of sugar has a natural tendency to commence from the sides of the mould, particularly when these are somewhat roughened. To prevent the formation of larger crystals on the external surface of the loaf, which necessarily leave larger interstices, the sugar in the mould is stirred with a wooden spatula, in the form of a knife, in such a manner that every particle is detached from the sides; and this operation is repeated after half an hour. The crystals are thus disseminated uniformly through the thick syrup, and afford so many points for the commencement of a uniform crystallization, which is completed in from fourteen to eighteen days.

A fresh stage of the process is thus brought about, and a compact network of small pure crystals of sugar fills the moulds, the interstices of which are filled with the mother-ley, or with a saturated solution of sugar. This liquor is impure, in proportion as the crystallized sugar is pure, and must be removed by dripping through; its thick state of fluidity is however a great impediment, and it is necessary to retain the temperature of the crystallizing-room at least at a temperature of 19° R. (75° F.) The usual temperature, however, generally exceeds 25° C. (77° F.)

The plugs are now removed from the moulds, and the syrup is allowed to flow off. At the expiration of twenty-four hours, when the running abates, the loaves are loosened by inverting the moulds, and detaching the sugar from its sides; the syrup is then enabled to get away more freely. The syrup that has been thus separated is called *green-syrup*, and is collected or allowed to run together from a connected system of gutters; it must be daily removed from the hot room, in order to preserve it.

It is better to arrange the moulds over wooden open pipes, lined with zinc, the upper surfaces of which are furnished with appropriate apertures to catch the drippings.

Four days and more elapse before the molasses have thus spontaneously separated. A residue, which is not sufficiently pressed upon from above, remains in the point of the loaf. The loaves are now removed from the moulds, trimmed and dried, while the brown point is broken off, to be remelted.

e.) *Claying.*

The first product, and still more the products obtained from molasses, are more or less coloured with molasses or syrup, which has been left in the interstices of the crystals. This residue of saccharine liquor is injurious to the colour, firmness, and dryness of the loaf; and, in order to bring these qualities to a higher state of perfection, certain additional methods of purification are resorted to called *claying*, which consist essentially in purification by displacement.

White clay.—The oldest of these methods, which gave the name to the operation, is effected by means of *clay*. White potters' clay, which is not so fat as to retain a large quantity of water, is washed, in order to remove from it the soluble ingredients, and is placed upon the sugar in the moulds, in the form of a uniform thin paste. The sugar to be clayed having been previously freed from the solid crust which forms on the surface (apex) of the loaf, the upper layer is loosened and scooped out, so as to form a cavity in the centre; the clay-paste is then placed upon it, 1 lb. at a time, in a layer of about 4 lines thick. The first water sickering from the clay drives the molasses before it, and is speedily converted into a saturated solution of pure sugar, by dissolving the crystals. The following portions of water form still purer saccharine solutions, all of which gradually sink through the loaf, and expel the syrup, the brown colour of which, descending at once towards the point of the loaf, at length entirely disappears. Nothing is then left in the mould but a network of pure, or nearly pure crystals, impregnated with a pure solution of sugar. A loaf of this kind, when dried, leaves pure sugar; that portion of the sugar which dries up from the solution, cements the crystals still more firmly together, and gives the entire loaf the requisite degree of solidity.

A single layer of clay is not sufficient to effect this purification, and the clay is generally once renewed. The syrup exuding from the loaf thus clayed is called *clayed syrup*.

With pure sugar.—The only object of the clay being to allow a pure solution of sugar to trickle through the loaf, and expel the impure green syrup from the pores, it soon appeared desirable to do away with the clay altogether, and substitute a pure saturated solution of sugar. These solutions dissolve no more of the crystals, having been previously saturated at the same temperature as that of the mould; they introduce no foreign substances, salts, or argillaceous matters into the sugar, and leave a pure surface, which requires no cleaning, as is the case where clay is used.

This method has come into very general use, sometimes the clarified liquor, sometimes a solution of pure sugar, being employed, and sometimes small quantities of pure water being sprinkled at intervals over the surface; in this latter case, the first advantage is not gained, and sugar is dissolved from the loaf.

Alcohol of 33° or 34° has the property of dissolving the syrup very easily, while crystalline sugar is little or not at all affected by it. Derosne endeavoured, in the year 1805, to substitute it for water, or sugar-water, in the claying process, with the greatest success; but the danger of fire, and the cost of alcohol in this country, has not favoured its general introduction.

It would take too much time to wait until the whole of the syrup has trickled through; when, therefore, it drops very slowly, and the sugar exhibits in other respects the proper condition, the moulds are inverted for a short time, that the remainder of the clay syrup, which is collected in the apex, and colours it brown, may be disseminated through the entire loaf, and give it a uniform appearance. The loaves are then separated by a blow on the edge of the mould, and again placed with their points downwards, that the syrup collected between the surface of the loaf and the side of the mould may drop off. When this is effected, they are placed upright, at first covered by the mould, which is removed before they are dried. The drying is first carried on in the air for a day, the moulds being removed, and is completed in the drying-chamber. The temperature of this chamber rises from 25° (77° F.) at the commencement, to 50° (122° F.) towards the end.

It is much better, instead of inverting the loaf, in order to allow the dark syrup to spread itself over the whole, to knock off the apex of the cone, and with a properly-constructed instrument, consisting of crooked knives, to produce a new top.

The dried sugar loaves form the first quality of sugar. A small quantity of the different kinds of syrup, which are secondary

products in the refining, is added to the water, for dissolving the succeeding portion of raw sugar; but the greater part is treated alone, and yields the different varieties of bastard sugar. The last portions retain so large an amount of syrup, that their grain is far too soft for loaves, and they are consequently brought as flour or powder into commerce.

It must be observed with reference to the treatment of these inferior syrups, which is conducted upon the same principles as that of the first quality, that the process of crystallization requires that they should be very much more slowly cooled. The granulated mass is consequently filled into very much larger moulds, called bastard-moulds, which are capable of holding 1 cwt. of sugar, and then are exposed to a higher temperature, in proportion as the sugar contained in them is less pure; the process of crystallization is longer in proportion. A portion of molasses is always obtained as a final product.

When a first-quality mould contains 30 lbs. of the granulated mass, about 10 lbs. of green syrup will drop from it, and there are left 20 lbs. of moist sugar, which correspond to 17 lbs. of dry sugar, if not clayed; but, after claying, only afford 11 lbs. of first-quality sugar.

If a bastard-mould contain 60 lbs. of granulated material of second quality, 25 lbs. of molasses will drop from it, and leave 35 lbs. of unclayed moist sugar, equivalent to 32 lbs. of dry sugar, which, after claying and drying, leave 17 lbs. of marketable produce.

Cost of claying.—The cost of the refining is not due alone to the refuse products, but more especially to the time expended on the processes, which obliges the refiner to keep a large stock of sugar always in progress.

The interest of the capital sunk in the stock of sugar has therefore to be added to the cost of the process. From the time the raw sugar is first melted, at least thirty-five or forty days must elapse before it can be returned as refined sugar into commerce, and still more time is expended in the treatment of the inferior qualities.

A refiner who operates at once upon 320 cwts. of sugar, is capable of delivering 160 cwts. of refined sugar daily, retaining an equal quantity on hand, or 6,400 cwts., at the expiration of forty days. When nearly an equal quantity of the inferior qualities is added to this, the stock of raw sugar, &c., some idea

may be formed of the large capital that must be sunk in this branch of manufacture, and the great gain that would accrue by any abridgment of the time expended in the last operations. Omitting the process of Derosne (p. 324), which yields refined sugar in six days, there is at present little prospect of effecting this.

Claying under pressure.—Whoever has investigated the attempts to improve and accelerate the processes for purifying sugar, cannot have failed to observe that everything depends upon the expulsion of the molasses from between the crystals, and that the thick state of fluidity of the molasses offers the greatest obstacle to the attainment of this object. It obliges the manufacturer to retain his rooms at a temperature that is very much opposed to the deposition of the sugar crystals. The mechanical powers have consequently been called in aid to separate the molasses, and although the attempt has not proved entirely successful, it is well worthy of notice. Chomel, in *Montreuil-sur-Mer,* employed the pressure of the atmosphere to expel the molasses from the sugar, by attaching the mouth of the mould to a Toricellian vacuum, produced by a barometrical column of molasses. The height of this column, from the great specific gravity of the molasses only requires to be about 23 feet.

The arrangements for purifying sugar by centrifugal force have been attended with good results as far as the second and third qualities are concerned, and these are rapidly freed from syrup by that means. The machinery consists of rapidly rotated perpendicular cylinders of wire gauze, which allow the syrup to pass through them. In many places the want of motive power might prevent this being carried into operation.

The drawings, Figs. 102 and 103, represent an apparatus for expelling molasses from sugar by centrifugal force, patented by Messrs. Rotch and Co.

A represents a drum, the circumference of which, *B*, is made of perforated metal or gauze wire.

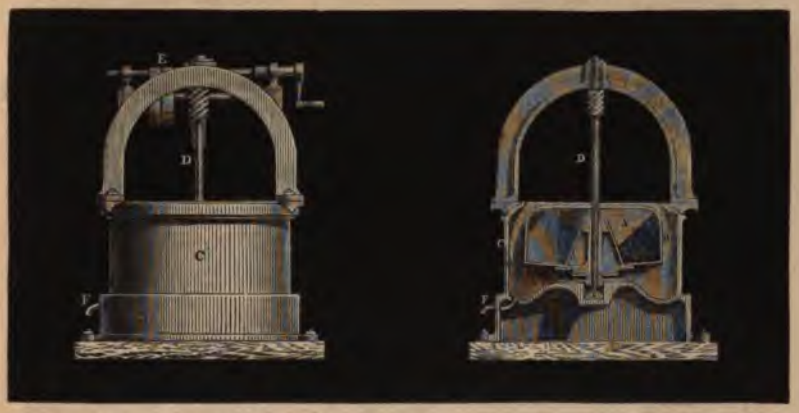
C is an exterior casing of cast-iron.

D is a shaft to which the drum *A* is attached.

The shaft *D* is driven by the gearing *E* shown in this elevation.

Mode of working.—The sugar to be operated upon being first properly prepared, as patented by Robet and Finzel, is placed in the drum *A*, which is put in motion by means of the gearing *E*,

FIG. 102. FIG. 103.



which drives the shaft *D* at a speed of many hundred revolutions per minute. The sugar by the centrifugal action is driven against the interior of the sides of the drum *A*, when the molasses escapes through the perforation, and is carried off through the cock *F*, the crystals being retained within the drum, and brought to any desired degree of whiteness.

The whole machine is about 4½ feet diameter, contains about 2 cwt. of sugar at each charge, which is refined in about eight minutes.

The machine requires less than one-horse power to drive it.

Mr. Bessemer has proposed some novel plans for the manufacture or purification of sugar. His patent consists of five improvements for separating fragments of the cane, &c., by means of a centrifugal filtering machine, from the juice, after it has been expressed from the canes; and the coagulated matters, by a similar contrivance, from the juice, after defecation. The evaporation of the juice, thus purified, is further expedited by the application of a centrifugal evaporator, and all foreign matter is subsequently removed from the juice, after the blowing up, by the same arrangements; and, lastly, in separating the sugar as it crystallizes. The various drawings in Plate 8, refer to the above plans, which are briefly described in the following pages.

On sheet *A*, the apparatus for separating the cellular tissue of the cane from the juice, is represented.

Fig. 1, is an elevation.

Fig. 2, a vertical section through the line *A B* of Fig. 3.

Fig. 3, a plan.

Fig. 4, a horizontal cross section on the line *C D* of Fig. 1.

Fig. 5, is a side elevation;

Fig. 6, a front elevation of a scraper;

Fig. 7, a cross section; and,

Fig. 8, an elevation of part of the perforated drum, on a larger scale.

a is the outer iron case of the machine, having brackets *b*, cast upon it, for the purpose of supporting the shield *c*. In the centre of the case is a shaft *d*, working on a pivot at *e*, and having its upper end supported by brasses *f*, let into a boss c^1, formed by the junction of the arms c^2 of the shield; one of the arms, c^3, serves to support a horizontal shaft *g*, working in plummer blocks *h* and *i*; one end of the shaft *g* carries a loose fast pulley, *j* and *k*, for the purpose of connecting any first mover with the machine. The other end of this shaft carries a plain bevilled cone *x*, working in contact with a similar one *y*, keyed on the vertical shaft *d*; so that the motion of the horizontal shaft may be transmitted in a similar, though quieter, manner to bevilled toothed wheels. On the shaft *d*, there is a drum *m*, made of sheet metal, having a conical part raised in the centre m^1, for the double purpose of preventing the matters operated upon from occupying the central space, and of giving strength and stability to the drum. The outer part of the drum is perforated with numerous holes (see Fig. 8), and exterior to this is a covering of felted wool, or other suitable filtering fabric; it is tightly stretched upon the drum, which is made slightly conical for that purpose; and over the felt is placed another thin perforated metal cone, which is drawn down tight over the felt by lacing, as shown at m^2, Fig. 2, and at m^2, Fig. 8. *l l* are studs around which the lacings pass, and by which means the outer perforated jacket is brought tight over the felt, compressing it firmly between the two surfaces, and thus protecting the felt or other filtering media from injury.

On the shaft *d*, there is placed a scraper *n*, having a tabular part n^1, fitted on the shaft *d*, so that it is free to revolve thereon. From one side of the cylindrical part, there projects a bent arm n^2, made of a triangular form, in cross section, and hollow, being made of sheet metal for lightness, and triangular for strength. The upright part n^3 of the arm has six inclined blades n^4, riveted to it; the face of these blades are curved, so as to fit nearly close to the inside of the drum. On the upper part of the tabular axis of the arm is fixed a grooved pulley *p*. A wire rope, or other

band, passes over this pulley, and by means of the guide-pulleys *q* is made to pass also over the grooved pulley *r*, on the shaft *d*. The band is passed in order that the drum and the scraper may both revolve in the same direction; but if the pulley *p* is a little smaller than the pulley *r*, then the scraper will revolve at a different velocity to the drum *m*, although in the same direction. This differential velocity will cause the face of the scrapers to move slowly over the interior surface of the drum, while each of them are revolving at a rapid rate. In the lower part of the casing *a* there is formed a chamber *s*, in which a centrifugal disc pump is placed, the disc *t* being keyed to the shaft *d*. The upper part of the pump chamber is covered with a plate *u*, which has a central inlet at u^1. The chamber *s* has a delivery pipe *v*, through which the filtered juice is forced to the defecating vessels, which are supposed to be placed several feet above the level of the filtering apparatus.

The action of the machine is as follows:

The driving strap being shifted from the loose drum *j* to the tight one *k*, the whole apparatus will be put in motion. The cane-juice is then allowed to flow into the drum by the pipe *w*, from whence it falls on to the bottom of the drum, and is immediately thrown off against the felted cone by the centrifugal force acquired by its rotation. The liquid parts will thus pass through felt, or other filtering material, and be received in the outer case; while all such particles of solid matter as may have been mixed with the juice will be retained, and form a coating on the interior of the drum, the inclined blades, which are all the while slowly gaining ground by its increased speed, will have the effect of raising the deposit, each blade lifting it within reach of the next, and so on, until it reaches nearly to the top of the drum, where it will accumulate; and, as the accumulated mass increases in bulk, portions of it, in a state approaching dryness, will be projected over the upper edge, and strike against the curved underside of the shield, from which it will fall perpendicularly to the base of the machine; while the liquid, passing through the felt, or other filtering material, will be collected and run into the centrifugal pump *t*, from whence it will be forced to any required part of the works.

Secondly, the filtration of the defecated cane-juice may be carried on with the apparatus just described; the hot liquor, in that case, from the clarifier, being allowed to run into the machine by the pipe *w*, and be discharged by the pipe *v* into the evaporating

vessels; or both this and the preceding operations of filtering may be carried on with either of the forms of apparatus described farther on.

The evaporation of cane-juice or syrups is much facilitated by centrifugal force, by which the liquors are elevated and dispersed in a shower, which falls down again into the evaporating pan in a more concentrated state, from having lost a portion of its watery constituents by evaporation, caused by the increased surface exposed to the action of the atmosphere while falling through it as a shower. The apparatus used for effecting this object is represented on sheet *D*, Plate 8.

Fig. 7 is an elevation, and

Fig. 8 a vertical section through the centre of the tube.

a is a copper tube, closed at the bottom, and terminating in an axis. At the lower part of the tube is an enlarged part *b*, with four vertical guides to keep the ball *c* in its place. Below the seat, where the ball rests, are four slots in the tube, to admit liquid to the interior of the tube, but which is prevented from returning by the ball-valve *c*. The upper end of the tube is joined to a double cone, the outer one *d* having numerous small perforations made in it; the inner one *e* is placed a small distance apart from the outer one, but both are connected at the upper edge, and thus a space is left between them. In the centre of the inner cone a small axis *f* projects upwards, carrying a grooved pulley *g*, by which it is put in motion. The bottom end of the axis is made to enter a small socket, formed in a piece of brass, and fastened to the centre of the bottom of the evaporating pan, while the upper end of the axis is supported by a small beam or other convenient part of the building, so that the tube may be made to revolve in a vertical position in the centre of the pan. The tube having been entirely immersed in the liquid, the air will be displaced, and the tube will become full of fluid. It is then placed in a vertical position, the band put upon the pulley *g*, and a rapid motion given to it, when the liquid will be projected in a shower over the surface of the pan *w*. The upper part of the cone being of larger diameter than the lower one, it will move at a higher velocity, and project the fluid to a greater distance; while those holes around the lower part of the cone will disperse the shower to a less distance as the cone diminishes, and thus distribute the shower very evenly. If a current of air be made naturally, or by machinery, to sweep across the pans, while the shower is falling, the vapours will be carried off,

and the evaporation increased. Whenever the apparatus is stopped, the ball *c* will sink down on its seat, and prevent the return of the fluid; the upper part will however empty itself, but not lower down than the lowest row of perforations, so that whenever it is again put in motion, the liquid will raise up the cone, and draw behind it a fresh supply from the pan.

The centrifugal filtering apparatus for separating the coagulated and other matters from syrups in the process of refining sugar, is shown on sheet *D* of the Plate 8; one form of apparatus for this purpose is shown at Figs. 1 and 2; the former being an elevation, and the latter a vertical section.

The fluid portions will be driven by centrifugal force through the pervious drum, while the solid and coagulated matters will be retained within the drum; and as the inclined scrapers have a motion somewhat quicker than the drum, their action will be to lift up the sediment from the lower to the upper, or enlarged part of the drum, in the manner already described in reference to sheet *A*, in the lower part of the drum. The centrifugal force is only sufficient to insure a rapid passing through of the liquor; but as soon as the sediment is received in the enlarged part h^1, which is also pervious, it is subjected to a very much more powerful centrifugal action, in consequence of the increased rate at which it revolves, whereby these refuse matters are dried sufficiently not to require any after process of pressing, as usually practised when such matters are taken out of filter-bags.

When the apparatus has been in operation some hours, and a large accumulation of these solid refuse matters has taken place in the enlarged part of the drum, the machine may be stopped, and these matters removed by hand, when the process may be continued as before.

In some conditions of the syrups, it is considered disadvantageous to bring them in contact with atmospheric air to any great extent. To avoid any injury from contact with air in the process of filtration, the apparatus shown on sheet *D* is proposed, where Fig. 3 represents an elevation, and Fig. 4 a vertical section.

The drum *h* of this machine differs from those before described, in having a close cover *w* bolted upon it. When this apparatus is to be used, the chamber a^2 and the drum *h* are both entirely filled with syrup; the centrifugal drum *h* is put in rapid motion by the driving drum *e*, when the centrifugal force generated thereby will drive a portion of the fluid from the interior of the drum *h*,

through the filtering media contained between the two perforated metal cones, as before described in reference to the apparatus shown on sheet *A*. The fluid, thus forced into the chamber a^2, can be conveyed to any desired part of the building by a pipe, connected with any part of the chamber a^2, but not shown in the drawings, while a fresh supply of liquid will flow into the drum by the pipe *g*, and issuing through the orifices v^1, will cause the arms *v* to revolve at a speed differing slightly from that of the drum *h*, whereby the matters which cannot escape through the filtering material are prevented from adhering to the interior of the drum. After working some time, it will be necessary to stop the supply of liquor from flowing through the pipe *g*, and also stop the revolving drum; the cock *n* may then be opened, and the impure contents of the drum allowed to flow out; after which the operations may be resumed in the manner before described.

Much difficulty has hitherto been found in keeping machines for curing sugar steady, in consequence of the unequally-balanced load which they have to carry; and hence a violent oscillatory motion is sometimes generated on them. A great wear and tear of the machines is the result, accompanied by a considerable amount of vibratory motion, which is imparted to the buildings in which they are worked.

The apparatus by means of which Mr. Bessemer proposes to obviate this, is represented on sheet *B* of the Plate 8, where

Fig. 1 is an elevation.

Fig. 2, a vertical section; and

Figs. 3, 4, 5, 6, 7, and 8, enlarged views of the peculiar universal ball-joint, made use of in the suspension of the drum.

The operation of the machine is as follows:

Rotary motion being transmitted to the short shaft *i* (Fig. 2), that motion is transmitted to the shaft *f*, which is suspended by its ball; thus the drum and its contents are free to revolve upon the true centre of gravity, and without stress upon the machine. In so doing, an undue amount of oscillation is prevented by the roller *n*, which limits the distance of the motion.

The mode of supplying the semi-fluid matters to the machines now in use for curing sugar, and the way in which such matters are removed from the machine, is a subject of much importance in the economy of this process. The mode previously used for this purpose is to supply the machine by pouring in the matters

from a large vessel while the machine is at rest, or nearly so; and after the matters have been operated upon by centrifugal force, and the fluid portions separated, the machine is again stopped, and the solid crust of sugar formed around the interior of the drum is dug out by a small shovel, and put into any convenient receptacle.

This operation takes nearly as much time as the operation of separating the fluid parts, so that the machine is kept idle for a long time during each day; while the workman in charge of the machine is, in turn, kept idle during the mechanical part of the operation. Now, to obviate the loss of time by the machine, and allow the operations to be performed by the man during the working of the machine, Mr. Bessemer constructs it in such a manner as will allow the removal of the centrifugal drum and its contents away from the machine at once, and its replacement by another drum, already charged with the semi-fluid matters, to be operated on; so that the machine, with its new drum and charge of materials, may be set going at once; and while it is being worked, the workman can employ his time in removing the sugar from the drum just taken from the machine; and having done so, he can re-charge it, prior to the stopping of the machine, when the change of drums will again take place, and the operations proceed in the same order as before, causing as little delay as possible to the machine, and providing full employment for the operator.

This form of apparatus is represented on sheet *B*, of the Plate 8.

Fig. 16, being an elevation;

Fig. 17, a vertical section;

Fig. 18, an elevation of the shaft or axis of the drum; and

Fig. 19, a vertical section of the drum, as seen when removed from the machine.

Whenever the machine is put in rapid motion, the semi-fluid mass will immediately leave the dish K^1, which is not perforated, and arrange itself evenly around the cylindrical part of the drum, and allow its fluid constituents to be driven off. In those establishments where very large quantities of saccharine compounds are required to be operated upon by centrifugal force, for the purpose of separating the fluid from the solid constituents, it may be desirable still further to economise the lost time of the machine, caused by stopping it to remove the drum, and also to dispense

with the operation of charging and discharging it of its materials. To effect this object an apparatus is constructed, as shown on sheet *C*, of the Plate 8, where Fig. 1 is an elevation.

Fig. 2, a vertical section; and

Figs. 3 and 4, details of some parts not sufficiently delineated in Fig. 2, to be readily understood.

If we suppose the machine to have been in operation, and a thick crust or wall of sugar *S*, lining the interior of the drum, and the space below the false bottom to be unoccupied, then we shall have the general condition of the machine. The perforations of the drum do not extend quite so low down as the false bottom; therefore, in that part of the space S^1, the matters under operation still maintain their semi-fluid condition, and therefore freely rise in the passage between the parts *M* and M^5. Now, if any semi-fluid matter is let into the central annular space from the pipe *P*, the centrifugal action will immediately impel it against the semi-fluid mass already occupying the space S^1, which will be displaced thereby, elevating the crust, or wall of sugar, adhering round the inside of the drum. The new portions, as they rise upwards, will lose their fluid constituents, and in turn offer a resistance to the new portions of fluid let into the machine by the pipe *P*. The rate at which the crust of sugar rises is thus made entirely to depend on the speed with which the fluid enters by the pipe *P*, so that its action admits of the nicest regulation. When the crust of sugar rises above the top of the drum *M*, it is thrown off by centrifugal force, and received into the large annular space A^1, from which a boy can scrape it through a spout *Q*, into the hogs-head *R*. The liquoring or washing of the crystallized mass may be performed by admitting the required fluid by the pipe *T*, which is perforated on the side nearest the sugar. The liquor will be separated from the rest of the fluid matter thrown off by the circular gutter *U*, which receives it, and from which a pipe may lead it away; and thus the operation of curing sugar by centrifugal force may be carried on continuously, as long as the machine is kept going, and the raw material supplied The extremely rapid rate at which centrifugal machines require to be driven, has hitherto been a source of much difficulty in their use. The wear is sometimes excessive, and the high temperature of the sugar-house is unfavourable for leather straps; and the great distance at which they are required to be worked from the steam-engine, renders the cost of intermediate gearing very great for the amount

of power transmitted. The action of steam is therefore applied direct to the machine, thus avoiding loss of power, and original cost of the gearing required for transferring this power from a distant part of the establishment.

This method is peculiarly applicable to sugar refineries, where steam-pipes already traverse every floor of the building. One of the modes of carrying out this part of the invention is represented on sheet *C*, of the Plate 8, where Fig. 9 is a vertical section, and Fig. 10 a horizontal section on the line *A B* of Fig. 9.

But a still more simple mode of causing the power of steam to act directly in producing motion in centrifugal machines for manufacturing sugar, consists in attaching a pair of emissive arms to the vertical axis of these machines, whereby the same revolving shaft which forms the axis of the emissive engine, is also used for the axis of the centrifugal drum, reducing the entire machine to one revolving piece.

Although the emissive steam-engine is very wasteful of power when applied through the agency of straps and drums to machinery requiring a slow motion, it is much less so when applied where high velocities are required; but when applied direct on the same axis as the drum of the centrifugal machine, a great reduction of its usual amount of friction is obtained; and it will be found in some cases more economical in power than the application of ordinary steam-engines acting at a high velocity, at a great distance from the source of power.

On sheet *B*, of the Plate 8, one of these centrifugal machines is represented, driven by the emissive engine. Fig. 12 is an elevation, and Fig. 13 a vertical section.

Another mode of supplying steam to the revolving axis of centrifugal machines, impelled by emissive arms, is represented on sheet *D* of the annexed drawings; Fig. 5 being an elevation, and Fig. 6 a vertical section of the apparatus.

The drums of centrifugal machines, as generally used, have been made of wire-work, strapped and braced diagonally on the outside, to give them the desired strength; but, notwithstanding these numerous stays, the wire-work is easily loosened, and soon requires repair; while the straps and braces on its exterior surface prevent that equal action on the sugar which is desired; those parts of the mass immediately behind the straps or stays being imperfectly cured, and of a darker colour than the rest of

the mass, by reason of the obstruction caused by them to the free escape of the fluid. The following modification has for its object the removal of this defect, and the construction of a durable drum equally pervious at all parts of its surface. A sheet of metal is formed into a cylinder, the two edges brazed and drawn through ties, after the manner of drawing-tubes; the interior is then cut into grooves by a circular cutter, these grooves extending half-way through the metal; they are formed in a line parallel to the axis of the cylinder. The grooved cylinder is placed on a mandril, and put in a lathe, when a series of concentric grooves are cut around the cylinder; these last grooves being at right angles to those before made, and like them extending half-way through the metal, it follows that a series of square holes will be formed all over its surface, while a cross or lattice-work of metal will remain connected together at every crossing. A portion of such a surface as this is shown in Figs. 8, 9, and 10, sheet *D*. The holes may thus be made fine enough to require no internal lining of wire-gauze, or they may be made larger, and the drum be lined in the usual way; or, instead of this mode of grooving, a cylinder of metal may be prepared and drawn in like manner, and, by a suitable apparatus, the whole of its surface may be drilled with small holes, as shown in Figs. 11 and 12, sheet *D*, all of which are to be conical, the smaller end being inwards, so that any grains of sugar that may enter these holes from within will not remain there, and obstruct the outflow of the fluid matters; but, by reason of the increasing size of the holes, they will readily pass out, and leave a free passage at all times. These holes may be made small enough to require no inner lining to the drum, or they may be made larger, and a lining be employed as usual.

In order to remove such grains of sugar as may adhere to or become embedded in interstices of the drum, a circular wire or other brush is employed, mounted on an axle, in a small frame, as represented at Fig. 13, sheet *D*. The frame *a*, in which the brush *b* revolves, has pivots at *c c*, which work in lugs, fixed to the inside of the casing of the centrifugal machines; a slot should be made in the case, to allow the handle *d* to project out; so that whenever it is found that the drum is clogged the handle may be pulled, and the wire-brush will be brought against the revolving surface; this will cause the brush to revolve also, and, by the action of the drum, the crystals of the sugar, which have been forced into the interstices of it, will be immediately displaced, and

the drum again made free. This operation is best performed when the drum is moving at a moderate rate.

These brushes would appear to obviate the serious objection made to the centrifugal machines in consequence of clogging. In practice, however, it is found necessary to blow steam through the wire gauze sieves in order to clear them of all clogging matters, and to prevent the sugar crystals being deposited in them by the cooling action of the machine. The amount of sugar obtained from the same amount of sugar-pulp, or sugar in the semi-crystalline state, is lessened by using these machines, and the amount of syrup of course proportionally increased. The sugar is of better quality, but is in the state called crushed sugar, and does not realize an extra price in the market sufficient to compensate for the lesser quantity of it that is obtained.

A process has lately been proposed by Dr. Scoffern for the defecation and refining of sugar which, if successful, would render the use of animal charcoal, and the process of filtration (a very expensive part of the ordinary process) almost totally needless.

The process consists in separating the whole of the colouring and foreign matters in the saccharine juice, by means of a solution of basic acetate of lead, the oxide of lead in which combines with these matters, and precipitates them in an insoluble form. The excess of the lead-salt, which must necessarily be employed in the first instance, is removed subsequently by saturating the saccharine solution, after its separation from the lead precipitate, with sulphurous acid gas, which produces with the lead an insoluble salt, the sulphite of lead, the excess of gas being itself afterwards removed by simple boiling.

The process has been carried out on a large scale in several sugar-houses, and is to a certain extent successful, although we have heard that the large proportion of molasses, and the bad quality of these to which it gives rise, are serious objections to it.

It was proposed to apply the process at once to the cane-juice in the colonies, but the Government, acting upon the advice of several scientific chemists of the highest reputation, have considered it necessary to warn the manufacturers of the dangerous nature of the process, if carelessly carried on, and indeed have strongly recommended that it should not be put in practice, on the ground that it is unsafe to use so poisonous a substance as the salt of lead in the manufacture of an article of general consumption, when the purification of that substance can be effected without it. The

quantities of lead detected in the sugar obtained by this process were so small as to be considered totally innoxious, although the bastard sugar and the treacle contained lead in a soluble form, and in one case in proportions which might excite apprehensions if the latter substance, treacle, were consumed in the same proportion as sugar. Unless carried on under the constant superintendence of a skilful chemist, the process has been consequently condemned as dangerous.

Stamped sugar is a product from the inferior qualities, generally lump-sugar, for which a higher price is sought to be obtained by giving it the shape and appearance of refined sugar of first quality.

Moist soft lump-sugar, is grated or mechanically divided, and the flour allowed to pass through a sieve to render it uniform, this is then stamped in layers while still moist into a damp first quality mould. It often happens that the separate layers do not cling to each other; but this may be avoided if the moist flour is filled into bronze or brass moulds, and forced down by two or three sharp blows in the direction of the apex of the mould.

This imitation of first quality sugar may be removed immediately from the mould and dried. Lump-sugar, only which is not much darker in colour than first quality sugar can be treated in this manner.

Large, well-formed crystals of sugar are known by the name of *sugar-candy*; they are specially prepared from a syrup which has been clarified with less charcoal powder than usual, and not allowed to pass through the charcoal filter. Sugar-candy, in other words, must consist of coloured crystals enclosing uncrystallizable sugar, if it is to exert its peculiar solvent action in affections of the mucous membrane of the throat. It should therefore never be prepared, or only in exceptional cases, from clarified or clayed sugar. In order to avoid the impurities and disagreeable taste, which the use of blood without subsequent filtration through charcoal would induce, the white of egg is substituted for blood in its preparation. A syrup is thus obtained, which, in order to increase its mucilaginous, sticky properties, should be boiled over an open fire, at least, not *in vacuo*, and for the darker kinds a higher temperature is required than for the lighter; the liquor is then allowed to crystallize in copper vessels. The latter have smooth sides, and are contracted towards the bottom, that the crop of crystals may be easily removed. At the sides are several rows of small holes at equal heights, through which strings can be strung. The apertures are afterwards closed

with paper (or with blood and ashes, or clay), and the vessels filled to a level above the strings, and placed in a kind of drying chamber, the temperature of which is maintained at about 40°—50° (104°—122° F.) Partly on account of the cooling of the syrup from the boiling temperature, and partly from the constant evaporation, a slow deposition of sugar in solid crystals is effected, in part on the surface, but mostly on the strings and sides of the vessel. The crystallization is completed in about six or eight days. In order to draw off the syrup, the surface crust is broken, and the vessels are placed in an inverted position, until the dropping ceases, when the crystals are removed and dried.

2. (*Cane*) *sugar from beetroot.*

Origin and varieties of the beetroot.—The vegetables which have been known for a long period by this name, and are cultivated as fodder for cattle, and have latterly been cultivated as raw material for the production of sugar, belong to the species *Beta*, of the family *Chenopodiaceæ* or *Atripliceæ*, and are biennial plants. Most of the very numerous varieties are derived from the *Beta cicla*, although several botanists consider *Beta vulgaris* as the mother plant of the beetroots.

The value of these varieties, in a practical point of view, consists entirely in the character of the thick fleshy protuberance of the stem, to which the actual roots are attached. The position of this bulbous portion, with reference to the soil, its shape, diameter, and colour, are the chief points to be attended to. The bulbous portions of some kinds of beet is formed below the surface of the earth; in others, it is above, exposed to the air; and again, in some it is placed midway between earth and air. Most varieties of the beet bulb are spindle-shaped; in some it is long and narrow, as in the radish; in others, thicker and more round, and of very different dimensions, when full grown; it is seldom flattened. While the fleshy part in many varieties is white, it is violet-coloured, orange, or yellow, in others; the interior is often white, and the skin alone coloured.

The varieties may also be distinguished by the extension of the crown of leaves, the size of the leaves and their stems; the shape of the leaves, whether they are curled or not; by their colour, which is either light or dark-green, or fringed with red, &c.

If a bulb is cut in the direction of its longitudinal axis, through the centre, the cut surfaces afford a clear insight into the structure

of the bulb. It will first be remarked, that the leaf-stalks take their origin pretty deeply in the body of the bulb, and there form an extensive region called the heart, which is characterized by its greenish colour and abundance of fibrous vessels, and in chemical constitution is more analogous to the leaf-stalks than to the rest of the bulb. The actual bulbous matter is distributed in a zone about this heart, extending below it to the point, and consists of concentric layers of fibrous vessels and cellular tissue, which alternate with each other. The cells contain neither starch nor crystalline salts, but only a liquid, consisting chiefly of dissolved sugar,* and of which the smaller cells, surrounding the fibrous vessels, contain a larger quantity than the larger cells, which lie at a greater distance. The fibrous vessels, on the other hand, contain no sugar, at least those do not which are situated in the heart; but they contain salts in a crystalline form.

Payen concluded, from his observations, that in the bulb of the beet, the fibrous layer, which constitutes its chief bulk, contains much more sugar (13 per cent) than the cellular layer (6.8), and that consequently the sugar is chiefly deposited in the tissue attached to the fibrous vessels.

Chemical constitution.—Numerous substances have been chemically separated from each other in the beet-root; and, in addition to those already named, the following have to be mentioned.

1. *Water.*
2. *Sugar.*—Pelouze and Peligot had already asserted that the beet contained only crystallizable cane-sugar. This most important fact has been since corroborated by means of Trommer's test.†
3. *Cellular matter* (*cellulose*). Parenchyma of the cells, which, existing in preponderating quantity, comprises the great bulk of the beet.
4. *Albuminous, nitrogenous matters.*—These occur in much less quantity than the foregoing. All the earlier analysts maintained that beetroot only contained albumen; but Hochstetter, by more accurate methods, has distinguished:
   a. Pure *vegetable albumen* (p. 4 and 79), which coagulates, when the fresh juice is heated to the boiling-point, as a white clot, that soon becomes grey.

* Raspail states that no sugar is dissolved in the ordinary cells, but he found it in the fibrous vessels, in a solid form. This is improbable.

† This test is founded upon the fact, that all the varieties of sugar, with the exception of cane-sugar, reduce the sulphate of copper to the state of suboxide.

b. Nitrogenous matter, which, when exposed to the air, is first reddened, then becomes brown; and, lastly, inky black, by reason of a genuine process of oxidation. This colouring is only produced by the action of the air (in a vessel filled with the juice, for instance, from the surface downwards), and is accompanied by a precipitation of the substance which occasions it. This colouring, to which the juice of the beet is subject, in common with that of apples, potatoes, &c., can be prevented by sulphurous acid and its salts. The black precipitate may be separated by filtration, and affords ammoniacal products, on distillation. It is easily soluble in potash, but is not again precipitated by acids, although it is only slightly soluble in weak acids.

This nitrogenous substance is not contained in the cellular tissue, but only in certain vessels of the bulb; so that a freshly-cut surface of the beet, when the latter is not squeezed, exhibits a number of black spots, wherever these vessels come in contact with air. It is neither coagulated by heat nor by lime. Salts of lime (chloride of calcium), on the contrary, form a white precipitate with it, which becomes instantly black, on exposure to the air. Acids prevent the blackening of this substance.

c. A nitrogenous substance, resembling gelatin, precipitated by lime, but not by chloride of calcium. It decomposes sugar in solution, even in the cold; the liquid becomes mucilaginous, and contains lactic acid.

d. A nitrogenous substance, which like *b*, is neither precipitated by boiling nor by lime, but can be thrown down by basic acetate of lead. According to Schatten, the amount of nitrogen in this lead precipitate is very variable; he obtained from one specimen of juice 0.082 per cent, from another, 0.024 per cent, and from a third no nitrogen at all.

e. Besides these, there are yet other nitrogenous bodies contained in the juice of the beet, which are not precipitated by any of the re-agents named, but which are thrown down by nitrate of silver.

These nitrogenous matters are not always simultaneously contained in the juice, nor are they always present in the same quantity. Thus Schatten obtained precipitates with basic acetate of lead

from the clarified juice, which, in the one case, contained 0.55 per cent of nitrogen; in the other, 0.15; and in a third, no nitrogen at all. The first two of these nitrogenous bodies are contained originally in the juice, and are normal constituents; to what extent this is the case with the others, or whether they are products of decomposition of the former, must be left for further experiments to decide; this much only is certain, that they are all decomposed with the greatest ease, and are amongst the primary causes which tend to convert cane- into grape-sugar, and otherwise deteriorate the juice.

Payen found 1.11 per cent of nitrogen in dry beet, of which $\frac{1}{3}$rd was due to the albumen. Horsfield, on the contrary, obtained from beetroot, which lost in drying, 82¼ per cent of water, 1.8 per cent of nitrogen. Upon the very probable supposition that all these nitrogenous substances are of an albuminous nature, these numbers would correspond with 11.54 per cent of albuminous matters, or exactly $\frac{1}{6}$th, or 6.16 per cent of the amount of sugar.

5. *Pectin.*—The juices of fruits and of most roots contain this non-nitrogenous substance, which, under certain circumstances, assumes the form of jelly. The juice of apples and pears, for instance, gelatinizes immediately after it is separated from albumen, by boiling, and is treated with alcohol. The jelly thus obtained, commonly called *Pectin*, leaves, according to Chodnew, 8.5 per cent of ash, and is indeed not a simple substance, but a mixture of the salts of gelatinous acids. Turnips contain, according to the same observer, ready formed in their juice—*pectinic acid* = $C_{28}H_{20}O_{24}$, (pure *pectin*) and *hyperpectinic acid* = $C_{28}H_{19}O_{27}$, both in combination with lime. Turnips become gelatinous in consequence, when digested with hydrochloric acid; treated with lime-water, they again acquire a ligneous appearance, and are rendered gelatinous again by acid, and so on. The cellular substance, composed of $C_{28}H_{22}O_{22}$, is very little altered in composition, when the gelatinous matter is extracted with potash; the quantity of these acids, as compared with that of cellulose, must consequently be very inconsiderable. They are converted into sugar by strong mineral acids, and bear the same relation in this point of view, to the turnip, that starch does to fruit and the varieties of grain. All these observations have been made by Chodnew on the turnip alone, but it is more than probable that they apply equally to the beetroot. Braconnot and Kuhlmann are of opinion, that the cellular

substance of the latter must be supposed to consist, for the greater part, or nearly entirely, of the lime-salts of these gelatinous acids.—(*Compare* Fremy, "Annales de Chimie.")

6. *Gummy* or *mucilaginous matter.*
7. *Fat,* like tallow, besides waxy matter (chlorophyll, ?).
8. *Colouring matters.*—An unknown odorous and aromatic substance; a peculiar substance, producing an irritating sensation in the throat.
9. *Inorganic constituents.*—The beet examined by Horsford, with 82¼ per cent of water, left, in the dry state, 5.02 per cent of ash; or, in the fresh state, 0.89 per cent; and consequently, for every 100 parts of sugar, 7¼ parts of mineral substances. Hochstetter found in a turnip:

	In actual weight. lbs.	Dry matter. Per cent.	Ashes. Per cent.
1. From good garden ground	1.5	17.6	0.97
2. From the Oderbruch	22.5	12.0	1.70
3. From a loamy soil	2⅛	19.8	0.97
4. From a sandy soil	1¾	17.2	0.64

The quantity of organic constituents is therefore inversely as the fertility of the soil and the size of the bulb. Of the ashes, about 70 or 80 per cent is soluble matter, and consists of carbonate, sulphate, muriate, and phosphate of potash and soda. The insoluble portion consists of carbonate, and phosphate of lime and magnesia, of oxide of iron and silica. The carbonates have been produced by the incineration of oxalates and malates, and the salts of the gelatinous acids. The greatest incongruities are found with reference to the nitrates of the alkalies. In turnips from a poor soil, these are often totally absent; while in the opposite case, as in No. 2, they often occur in considerable quantities.

In order to afford a better insight into these quantities, we subjoin again the often-cited results of Horsford, perfected by those of Krocker:

Beetroot grown at Giessen:

	Fresh.	Dry.
Albuminous matter	2.04	11.5
Sugar	12.26	68.8
Cellulose and other nitrogenous substances	2.56	14.6
Mineral substances	0.89	5.0
Water	82.25	—
	100.00	99.9

It is generally admitted that the juice of the beet contains ammoniacal salts, and indeed the explanation of the phenomena occurring during clarification has been grounded upon the presence of these salts. This is due to an erroneous conclusion drawn from the correct observation, that the juice of the beet, during and after clarification, evolves ammonia. Neither the juice nor pulp of the beet, nor the sliced bulb, emit ammonia, when treated with lime in the cold; even upon passing hydrogen through these, after they had been boiled, no ammonia could be condensed by hydrochloric acid, which however immediately resulted, when salammoniac was added to them. The same is the result when the juice is heated with alkali or lime. The evolution of ammonia having once ceased, can be again induced, by allowing the juice to remain at rest for some hours. From 10,000 parts of juice, 3.3 parts of pure ammonia have been obtained, which amounts to about 3 per cent of the nitrogenous matters. The evolution of ammonia is consequently no separation of the volatile alkali from its ready-formed salts, but rather a formation or production of ammonia, by the agency of the alkalies or of lime upon those nitrogenous ingredients of the juice, which are neither precipitated by lime nor by a boiling temperature.

In order to ascertain to what variation the qualitative chemical constitution of the beet is subject—whether certain substances are present in one species, and absent in others—a numerous series of comparative analyses must be furnished. In the absence of such a series, a certain amount of knowledge may be deduced from the exclusive experience obtained in the manufacture of beetroot sugar; and these all tend to prove with certainty that the same substances essentially occur in all the varieties of beetroot. The more important, however, for practical purposes, is the variation in the relative proportions by weight, in which the different ingredients occur; and here we find, by quantitative analysis, that hardly two bulbs will yield the same results. According to existing statements, the discrepancies are occasioned, by the species of the beet, by the soil, climate, season, and weather, by the mode of cultivation, the state of ripeness or age of the bulb, and by other adventitious circumstances.

In the sugar manufactories, the following varieties have been practically applied:

1. The *large field beet* (*Disette*, of the French), with white flesh and a white skin. Some varieties are marked with red and white rings alternately, on the cut surface; the leaf-stalks are white.

Of all the varieties, this one attains the greatest size, weighing as much as 25 lbs. and more. One bulb, grown by Pommier, in the Departement Bois le Comte, near Vitry, weighed 26 lbs.; one, by Lafayette, weighed 28 lbs.; one, grown by Kilmoran, as much as 34 lbs. It grows to a considerable extent above the surface of the earth. Its juice is about 6° B. (=spec. grav. 1.04.)

2. The *Silesian beet* generally possesses white flesh, and occasionally rose-red rings. It is more pear-shaped than in the form of a spindle. Smaller than the preceding variety, and less deeply imbedded in the ground, it requires no such expensive preparation of deep soil. It is not exactly rich in juice, but rather hard, and hence, although more difficult to grate, it is less susceptible of injury from mechanical agents, or from frost, both of which easily produce decomposition. The juice of this variety, abounding in sugar, stands at 7° to 10° B. (=spec. grav. 1.05 to 1.07), and, in consequence of its purity, is most easily operated upon for sugar.

3. The *yellow beetroot* is also pear-shaped, and of medium size. The leaf-stalks are not white, but yellowish-green; the flesh is very soft, yielding a juice of from 5° to 7° B. (=spec. grav. 1.03 to 1.05).

4. The *Siberian beet*, first recommended by Reichenbach, is brought from Russia Proper, where it is cultivated for fodder. It is plate-shaped, and the bulb grows entirely above the surface, requires consequently a less depth of soil than any other, and is most easy of cultivation. On account of its growth above the soil, it is very easily gathered, which is of importance when the soil is stiff. The plate-shape of this variety, spreading over the surface shades the ground, and retains it much longer moist. This variety is said to be softer, and more easily grated than the Silesian, yielding from $\frac{1}{6}$th to $\frac{1}{8}$th more juice, containing about the same quantity of sugar (Reichenbach). Herrmann's statements are, however, totally opposed to these, who found a much less proportion of sugar in this beet than in the Silesian. Further experiments carried out in the manufactory must settle this question. The Siberian beet ripens fourteen days earlier; a white and red species are distinguished: they are also characterised by a lesser development of leaf, in consequence of which, the locality where these are inserted, or the heart, is much less capacious, with a smaller sugarless head to the bulb.

The same character applies to the Quedlinburg beet, which is much cultivated about Magdeburg; and, according to Simens, is common to all varieties of beet with a reddish skin and small

development of leaf, and which have long, thin leaf-stalks, with a distinctly-marked red rim on the upper part.

Of the species above-named, the *Silesian beet* is most highly prized by the sugar manufacturer, and is chiefly cultivated for the production of sugar, more especially in France; not so much in consequence of the absolute quantity of sugar it contains, but on account of a combination of properties which have all an equal effect upon the manufacture; these are, firstly, the large amount of sugar in the juice, and the absence of salts and other ingredients, which exert an injurious action upon the sugar in the course of boiling, and diminish the value of the product, or impede the process; and, lastly, its property of resisting putrefaction, which enables this bulb to be kept for a season with the least amount of loss.

Influence of the weight of the bulb.—Some very accurate and important rules have been established by experience, with reference to the effect of the state of development upon the quality of the bulb; and these apply to its size and age. In one and the same species, the watery character of the bulb increases with its weight, or, in other words, the saccharine matter is diminished in an equal weight of bulb. Thus Herrman found:

	In the Silesian beet.				In the Siberian beet.	
The amount of sugar per cent.	11.4	9.4	9.5	7.4	5.9	5.1
Relative weight of the bulbs in ounces . . .	6	13	23	45	16	40

In European Russia, up to 56° north latitude, the beetroot bulb, weighing from

4 to 8 ounces, contained 10 to 13 per cent of sugar.
8 „ 16 „ „ 9 „ 12 „
16 „ 32 „ „ 8 „ 11 „
32 „ 64 „ „ 7 „ 10 „

At Tobolsk, in Siberia, the bulbs, weighing from 16 to 19 ounces, afford 4½ per cent of sugar.

Influence of the degree of development.—Peligot has further shown that the beet, at all stages of its growth, including the period of its flowering, exhibits the same relative proportions of water and solid ingredients; and that consequently half-grown

and full-grown bulbs, flowering and not flowering plants, leave very nearly the same amount of dry residue. With the period of bearing seed, this residue rapidly diminishes in quantity, as will be seen from the following analyses:

Locality and state of the beetroot.	Date of Harvest.	Weight.	Solid residue, per cent.	Amount of Water, per cent.	Amount of Sugar, per cent.
Botanical garden in Paris .	2 Aug.	20—25 grm.	9.5	90.5	5.0
Ripe beet (late sown) .	29 Dec.	0.3 „	13.7	86.3	5.9
Botanical garden in Paris .	7 Sept.	800—900 „	10.0	90.0	7.3
Grenelle	7 Aug.	300 „	15.5	84.5	8.9
Botanical garden in Paris .	26 Sept.	80—100 „	15.1	84.9	10.0
„ „ „	9 Nov.	150 „	14.7	85.3	—
Ripe beet from Grenelle .	15 „	—	19.6	80.4	14.4
Beet in blossom . .	—	200 „	16.5	83.5	9.8
Beet two years old in seed .	—	—	5.5	94.5	0

It appears from the figures in the last column, that the amount of sugar in the beet gradually increases with the growth, and attains a maximum, at a certain period, before ripening, when it again diminishes, and disappears with the formation of the seed. While the sum of the solid ingredients remains about the same, we must infer that (independently of sugar) before ripening, a certain ingredient diminishes in quantity, and after ripening, another ingredient (woody fibre, ?) increases. That which is here called ripening, with reference to the sugar in the beet, is chemically quite distinct from the process concerned in the production of sugar in fruits, which is not active from the commencement, but begins all at once at a particular and later period, and has special relation to the vegetable acids.

Influence of culture.—Culture exerts a very perceptible influence upon the beet, both as regards the choice of a soil, the rotation of crops and manure. A heavy compact soil is expensive to work, renders the harvesting laborious, and obliges the root to throw out more small shoots and branches, which are with difficulty removed and never desirable. A very light sandy soil, on the other hand, yields too poor a crop. A proper medium between the two extremes should therefore be sought; for instance, a light clay soil; and the species of beet should be selected to suit the circumstances. However much a certain amount of humus in the soil encourages the growth of the beet, yet too much or too fresh manure has been shown, by dear-bought experience, to be objectionable, as the plants then absorb so large a proportion of saline

matter as to render the extraction of the sugar extremely difficult. For this reason, it is a universal practice, after the application of manure, to allow at least one, sometimes two, and often three crops to precede the beet. As a special manure, ashes and such refuse are chosen, which are active, from the mineral ingredients they contain, and do not increase, like farm-yard manure, the nitrogenous ingredients of the bulb. It is also of importance whether the seed is sown upon the field at once, as is the usual custom, or whether the plants are transplanted upon it; the time of harvest being materially hastened by the latter plan. According to Köchlin, two months are gained upon the ordinary time of ripening, when the plants are forced under glass shades, and transplanted in March. They then attain, when allowed to ripen fully, a weight of 30 lbs., and the hectare of land is said to yield four times more than usual, where in bad years a crop of 50,000 lbs., and in good seasons, 80,000 lbs., is considered ample.

Beet requires moisture, particularly in the early periods of its growth, and heat, in order to develop its full size and good quality. An excess of moisture is very rapidly absorbed by beetroot; in one case, it was observed that the contents of the juice were diminished after rain by 2° B. Very dry weather increases the amount of sugar in the juice, but lessens the total quantity of produce, as the bulb is not then capable of attaining its full dimensions. Very wet weather does not interfere with the growth, but lessens the total quantity of sugar produced, as it diminishes the amount contained in the juice; extreme wet or dry seasons are therefore alike injurious. Crespel obtained by the same methods of manufacture, in the year 1834-35, 8 per cent; and in the following year only 6½ per cent of marketable sugar.

A very general evil, which is connected with the climate, is the late ripening of the beet, which obliges the harvest to be deferred to the wet season of the year. A district like the south of France is consequently better adapted to the culture of beet, than either northern France or Germany.

Disease of the beet.—Amongst the casual influences, which sometimes threaten the beetroot harvest, the disease observed by Kuhlmann and Payen, in France and Belgium, in the year 1846 may be noticed. The leaves of the beet thus affected, become withered and depressed, and reddish-brown spots appear upon the skin, which gradually spread over the entire surface, and into the interior; the flesh becomes hard, woody, and the juice scanty in

quality, deficient in sugar, and exhibits an alkaline, in place of the normal acid reaction. The sugar loses its property of crystallizing, and the juice is difficult to manage throughout the whole process, particularly in boiling, affording a diminished and deteriorated product. Microscopic observations have established a most complete analogy between these appearances and those of the potato disease; the presence of a fungoidal vegetation, consisting of granules and fine threads, being distinctly perceptible in both cases. In what manner these fungi, which are destroyed by a boiling temperature, can pass over into the manufactured sugar, in the loaves of which, according to Payen, they actually eat out great holes, is very difficult to conceive.

Another remarkable case, which clearly proves how prejudicial an amount of common salt may be to the sugar, happened near the salt-works at Manheim. A field, in front of the graduation-house, was sown with beet, in the ordinary rotation of crops, for the purpose of producing syrup, to mix with the commercial sugar for domestic use. A good-looking crop was obtained, which yielded however, a tasteless, scarcely sweet juice.

It is obvious that the salt, which is carried away in abundance by the wind, had impregnated the soil, and acted upon the sugar, with which, as is well known, it forms a crystalline compound.

Relative dependence of the production of beetroot upon agriculture.—The home production of sugar involves two extensive branches of industry—*agriculture*, and, dependent upon it, the *production of beetroot sugar*. The relative dependence of these branches upon each other is one of the greatest difficulties with which, in competing with the produce of the colonies, this branch of manufacture has to contend. In order thoroughly to comprehend this relative dependence, it must be borne in mind, that it is not the interest of the sugar manufacturer to obtain, by means of beetroot, the greatest amount of sugar from a given surface of land. His interest lies, under the existing condition of the manufacture and its imperfections, in obtaining a juice in which the sugar is purest, *i. e.* in which it is accompanied by the least possible quantity of those ingredients which render its production and purification difficult. No intelligent sugar manufacturer will for a moment hesitate in choosing between a large amount of sugar per acre, disseminated through a great bulk of weak juice, saturated with saline matter, both of which tend to promote the production of mucilaginous sugar, and prevent the formation of crystals; and a

lesser amount of sugar per acre, contained in a more concentrated and purer juice, which implies a safe and well-regulated system of production. The real problem to be solved consists in obtaining not as much sugar, but as much marketable or crystalline sugar as possible, by means of the beetroot, from a given quantity of land. From this point of view, it is obvious that the manufacturer, with impure and diluted juice, does not gain his object, as the larger amount of water, and the salts with which it is impregnated, increase the expense of manufacture, tend to favour the production of mucilage and treacle, and render a large portion of the sugar unsaleable. One portion of the sugar, which may be considered as latent, must always be sacrificed, in order to obtain the remainder; and so much the more in proportion as the juice is impure.

This explains why it is, that an absolutely greater produce in sugar may sometimes be a disadvantage to the producer, and it becomes obvious that the question respecting the production of sugar in Germany is also a question of beetroot culture. This difficulty will always exist until the pure agriculturist thoroughly understands the interest of the sugar manufacturer, and takes measures accordingly to prevent the recurrence of those very numerous chances which threaten the former with a crop of beet ill adapted for his operations. Most sugar manufacturers are at present obliged to grow their own beet at a greater cost for land rent than under other circumstances would be necessary.

The progress of the home production of sugar is consequently mainly dependent upon the improved cultivation of beet, and in addition to this the still very imperfect manipulation obliges it to seek the protection of a duty in order to compete with colonial produce.

Review of the chemical constitution of the beet.—The results of some researches into the chemical nature of the beetroot have been already adduced at page 340. In determining the amount of sugar in the beet, the result is very much influenced by the mode of operation. Thus Hermbstädt obtained 4.5 per cent of crystallizable sugar and 3.5 per cent of mucilage sugar; since, however, the amount of sugar has been estimated by the fermentation process or by extraction with strong alcohol, crystallizable sugar alone has been obtained, and the results of different experimenters may now be compared, as will be seen from the following table:

	Peligot.			Pelouze.	Bra-connot.	Hoch-stätter.	Hermann.	Krocker.
Crystallizable sugar .	10.0	14.4	9.8	10.0	10.6	10.5—11	9—12	12.2
Pectin (with traces of gum, a nitrogenous substance, and salts	1.8	5.2	3.4	—	2.1	—	—	—
Woody fibre and albumen . . .	3.3		3.3	2.5	3.1	—	—	—
Water . . .	84.9	80.4	83.5	—	84.2	—	—	—
	100.0	100.0	100.0		100.0	—	—	—

The substances dissolved in the juice are, according to Hochstätter:

Sugar	83.6	86.3
Organic matter precipitated by lime . . .	8.0	7.5
„ „ „ „ subacetate of lead .	0.7	0.9
Saline matter	7.7	5.2
	100.0	99.9

The mean quantities contained in the beet are therefore

10	per cent sugar.
3	„ „ pectin, soluble salts, &c.
83	„ „ water.
96	„ „ of juice.
4	„ „ albumen, woody fibre, insoluble salts.
100	

The juice of the beetroot is subject to fermentation like that of the sugar-cane, and this is generally the mucilaginous fermentation. Mannite ($=C_6H_{14}O_6$) is produced in this process at the expense of the sugar, and a kind of mucus precipitated by alcohol which resembles gum-arabic in appearance and composition. The analysis of this substance yielded:

Carbon . . .	41.45
Hydrogen . . .	6.1
Oxygen . . .	52.45
	100.00 (Kircher).

According to Fremy and Boutron, lactic acid is formed by a slow decomposition in dry beet at the expense of the sugar.

Preservation of the beet.—Another no less fruitful source of difficulty than those already recorded, consists in the necessity of preserving the bulbs during the period the manufacture is going on, or from the beginning of October to February or March. In a vegetable substance that contains four times as much water as solid matters, and amongst these latter substances, sugar and albumen, which are so extremely prone to decomposition, particularly in dilute solutions, the preservation is no easy matter. The difficulty is more than usually great in this case, as it is not only the bulbs but the juice that must be preserved, and this in a state fit for subsequent treatment, and as like that of well-grown fresh bulbs as possible. An incipient state of decomposition may not materially alter the value of the beet as fodder for cattle, but would be very difficult to manage in the sugar process, and only half productive. Frost and rot are the two destructive agencies principally to be provided against. The latter is chiefly aided and promoted by a close atmosphere and by injuries to the external skin, which are of easy occurrence in the harvesting or carting the bulbs.

The older and common practice consists in storing the beet-roots in pits dug in the field, covered with straw and a thick layer of earth. A depth of from 4 to 5 feet is best as the great weight of the upper layers would be liable to damage the lower ones if the depth were increased. To ensure a thorough ventilation, narrow gutters are made longitudinally in the soil under the heap, and upright posts surrounded with straw are placed in the pits at certain distances from each other, around which the bulbs are piled up; when these sticks are afterwards withdrawn, perpendicular apertures are left, which being in connection with the channels below act the part of chimneys.

When the same pit is used several successive times it may easily happen that the residuary portions which may have been left and undergone putrefaction, will induce the same change in the entire stock of fresh bulbs, and so destroy them. As the decomposition of the sugar in the beet is chiefly due to the oxidation of the nitrogenous ingredients, the practice of impregnating them with sulphurous acid is truly scientific, and has been found beneficial.

Some of the better factories have commenced, with success, to construct covered storehouses above ground, in place of the pits. Although more costly in the outset, they eventually repay the first

outlay, by preserving the beet better, and affording a thorough ventilation.

Neither of these methods of preservation are, however, satisfactory, as in both cases the quality of the bulb is materially impaired. Many competent persons have consequently endeavoured to devise methods for avoiding the necessity for preserving the bulbs in their natural state. Schützenbach's method is the most important of these, which consists in drying the bulbs cut up into slices immediately after the harvest, preserving them in the dry state, and extracting them in the manner described at the end of this chapter.

The slices are prevented turning black, on drying, by sprinkling lime over them, according to Lirac; or with charcoal powder, according to Forbin Janson. These methods, particularly the use of lime, have an additional advantage, in preventing the formation of lactic acid.

PRODUCTION OF SUGAR FROM BEETROOT.

The operations employed in this process may be subdivided into *the preparation of the juice;* including *a*, washing; *b*, rasping; *c*, pressing the beet: and *the preparation of the sugar from the juice;* which comprises, consecutively, *d*, the clarification or defecation; *e*, the first filtration and evaporation; *f*, the second filtration, or fining the juice, and boiling the liquor; and *g*, the crystallization of the sugar.

A. PREPARATION OF THE JUICE.

a.) *Washing.*

As the saccharine juice is only contained in the actual substance of the beet, it is necessary, in order to obtain pure and rich juice, to remove not only earth and sand, but also the fibrous roots, all the bruised and rotten parts, and the heart. The fibrous radicles are generally removed at the harvest-time, and the heart is usually left as too troublesome to remove; so that the preparation of the bulb is restricted to washing off the sand and earth, which would be very injurious to the rasping apparatus, and unnecessarily render the juice impure.

The beetroot was formerly cleaned by hand, with the aid of brooms; but this practice has now been universally superseded by

the use of a machine, called, after its discoverer, Champonnois' washing-drum, and shown in Figs. 104 and 105. The principal part consists of a wide drum, or hollow skeleton cylinder, *b b*, 11 feet long by 3.6 feet diameter. On the axle *e*, two wheels, each with four spokes *n*, are attached; laths 1½ inches in thickness are fixed upon these by hoops at distances of 1 or 1½ inches from each other, and these form the curved surface of the drum. A driving band, connecting the drum *f* with the source of motion, causes the cylinder to revolve upon its axis. The drum is immersed in water to about the half of its depth. The bulbs, introduced by the hopper *a*, are constantly raised to a certain height by the motion of the drum, and caused to fall back upon each other. As this occurs under the surface of the water, the bulbs scour each other thoroughly; the dirt passes through the open spaces between the laths with the water, which is changed from time to time, while the clean bulbs are delivered at the front part of the drum. The advance of the bulbs from the hopper, towards the front of the drum, is caused by the inclination of its axis; and once arrived there, they are raised by a shovel *i*, curved in the form of a screw, and thrown upon the lattice-frame *d d*.

FIG. 104.

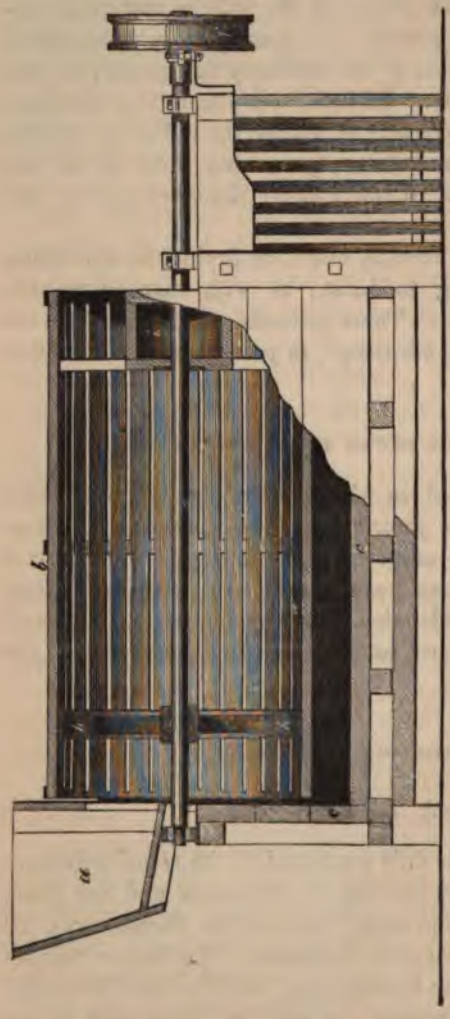
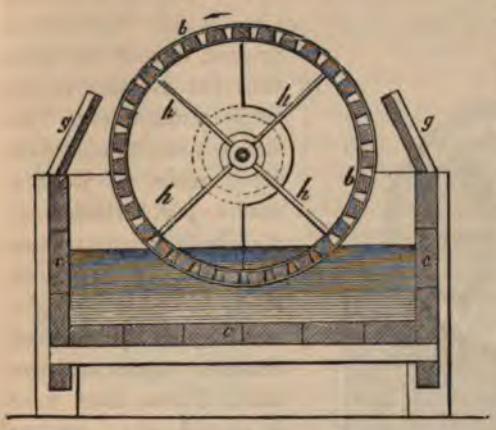


FIG. 105.



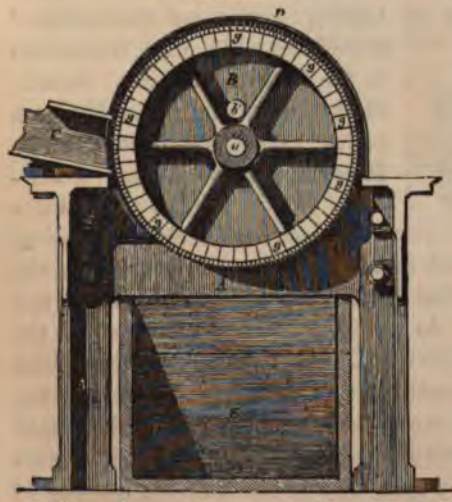
The letters *g g* indicate the position of splashing-boards. It is obvious that the machine, to fulfil its object, must only move at a moderate pace.

b.) *The Rasping.*

For reasons, which were explained in treating of the production of starch, it is necessary, in order to render the squeezing operations effectual, to destroy or open the cells containing the saccharine juice. This is done by tearing or rasping, which converts the beet into pulp. Simply cutting the beet into slices, is by no means sufficient to allow the presses full play.

Good healthy bulbs may be treated at once, after washing; if, on the contrary, a bruised stock, or one injured by keeping, has to be manufactured, it is absolutely necessary to remove the rotten and mouldy portions, which contain damaged juice, and would tend to induce speedily a like decomposition in the healthy juice.

FIG. 106.



Thierry's grating-machine.—The necessity of operating rapidly with beet, in consequence of the tendency of its juice or pulp to undergo decomposition, is in itself, independently of the saving of expensive hand labour, a sufficient reason for the introduction of machines for rasping or grating the bulbs. The grating-cylinder of Thierry (Fig. 106) is now almost universally employed. This

machine consists of a hollow cylinder or drum, the surface of which is thickly studded with teeth, so as to present a surface resembling a rasp on a large scale, against which the beet is pressed during the time that the cylinder is rotated by machinery. The drum is surrounded first by a series of wooden staves *g g*, which are attached between two cast discs or wheels *B*, each of which is strengthened by six spokes, and revolves upon an iron axis. These discs have a curved rim, against which the staves are firmly driven, so that they fit exactly into their periphery. The staves, which thus form the curved surface of the cylinder, are retained in their places by six screws and nuts, which connect the two lateral discs firmly with each other. Upon this cylindrical surface, which must be accurately turned, the armature or tearing instrument consisting of saw-blades (Fig. 108) is attached in the following manner. A lath, of the length of the saw-blade, is nailed upon the drum, in the direction of the staves; a saw-blade is laid against this, and a second lath nailed close up against it; then another blade, and so on, over the entire surface of the drum; care being taken that each blade is firmly clamped, and that the teeth of the one do not correspond with those of the following, but alternate with them. As the laths are just thick enough to allow only the teeth of the saw-blades to project, two flat zones are formed at the two edges of the cylinder, of the length of the handles of the saw-blades *a a*, round which iron hoops are bound, which, enclosing the ends of the laths with the handles of the blades, bind the entire rasping apparatus firmly together. The saw-blades, 150 in number, are $\frac{1}{16}$th of an inch in thickness,

FIG. 107.

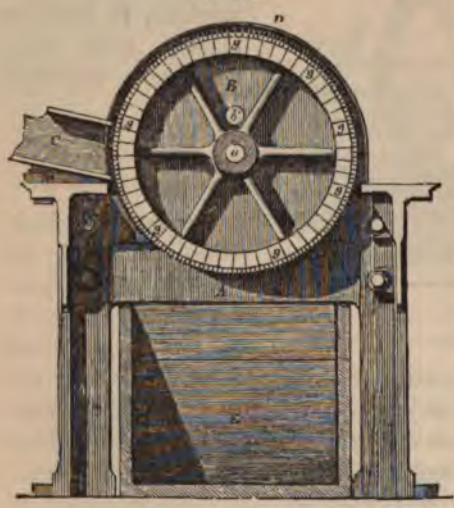


FIG. 108.

13 inches long, and 1 inch wide, with teeth $\frac{1}{8}$th of an inch in length. They are tightened in their places very much by the swelling of the laths between them, when the apparatus is in use. When the teeth become blunt, the blades are first reversed, and afterwards may be exchanged for new ones. The entire drum is placed in the iron frame *A A*, under which is a moveable trough *F*, for the reception of the beet pulp. The bulbs are pressed against the rasping surface through the double hopper *c* (shown separately in Fig. 109, *a* and *b*), which is attached to the plate *m*, either by the hand of the workmen, or, to prevent accident, by means of the block of wood *b* (Fig. 109). That this may not come in contact with the teeth of the saw, a projecting piece *x* (Fig. 109, *b*) is attached to it, which strikes at the proper moment against the upper edge of the hopper. The residual portions of the first bulbs are forced against the teeth by those which follow. The two divisions of the hopper are filled alternately, and not at once; by which arrangement time is saved.

FIG. 109.

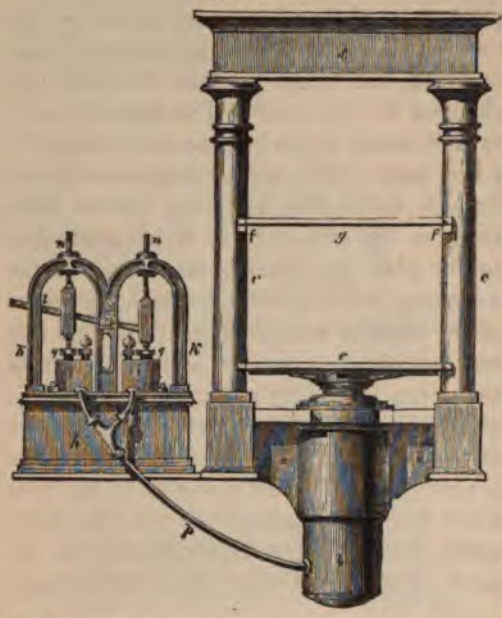
The drum performs 5—700 revolutions per minute, so that each tooth, on the surface, has a velocity of 800 to 1000 feet per second. With this velocity, the machine converts 250 to 300 cwts. of bulbs into pulp daily; the pulp would be forcibly projected about, if not prevented by the lid *D* (Fig. 107) covering the upper part of the drum.

c.) *The Pressing.*

For the numerous reasons already stated (the great tendency of the juice to spoil) the beet-pulp must be rapidly submitted to a uniform pressure, as delivered from the rasping-machine. After numerous experiments with other forms of presses, Bramah's hydraulic press (Fig. 110) has been universally adopted of late years as the most powerful, and admitting, at the same time, of a larger quantity being pressed at once; while the machine itself, from its compact construction, occupies a very small space.

The hydraulic presses, employed in the sugar factories, are always upright presses; that is, presses in which the pressure is

FIG. 110.



exerted in a perpendicular direction from below upwards, as is shown in Fig. 110, the motion being communicated by a double pump *k k*. The piston of the one barrel is raised, while that of the other is lowered by each stroke of the handle *l*. The construction of these pumps, described in Vol. I. p. 116, is very convenient, where a weaker pressure and greater velocity in the commencement are necessary; towards the end, however, the entire amount of pressure, with a diminished velocity, can be commanded. Time is thus gained, without impeding the thorough completion of the process.

A machine of this kind is calculated to exert a pressure of 300 lbs. on every square inch of the surface-plate *e*; so that, if this latter comprise 800 cubic inches of surface, the beet pulp placed upon it will be subjected to a pressure of 24,000 lbs. The larger the plate of the press, the more beet pulp can be pressed at once; but the more will the pressure exerted by the piston of the pump be diffused, and will require to be increased, if the same amount of pressure (300 lbs. on the square inch) is to be retained unimpaired.

The press is supplied in a regular manner with pulp, placed in bags prepared specially of unbleached hemp of an open texture, but of stout material. These bags are of the same shape but somewhat smaller than the plate of the press. When the proper quantity of beet-pulp has been placed in the sack, it is laid by the workman upon a table in a wooden framework, and by means of a wooden instrument the pulp is spread out equally over the breadth and length of the sack. It then forms a layer of the thickness of

the frame, and is generally 2 inches thick by from 500 to 600 square inches surface. The open end is turned in, and a hurdle of plaited willow twigs is placed upon the sack, a second sack upon that, then another hurdle, and so on, so that the entire heap is regularly piled. Half the number of sacks are placed upon the piston-plate *e*, the other half upon the middle plate *g*, so that the entire space between *e* and *d* is occupied. The sides of the sacks that are turned over must alternate with each other in the four directions, that any one side of the pile may not be thicker than the other. The hurdles, which are constructed of peeled willow that has been previously boiled to remove the bitter and extractive matters, are intended by their position between the sacks to form channels for the easy flow of the juice.

Two presses are always worked in conjunction with one rasping machine, that the one may be emptied while the other is at work. The pressure must be very carefully applied at first, and regulated by the flow of the sap, the pump only being set in action when the juice ceases to flow. The greater portion of the juice is generally expressed in about ten minutes; the residual portion requires about fifteen minutes more, when the pile is reduced to about three-sevenths of its original height.

It is obvious, that with all practicable care and the best possible arrangement of the press, the beet-pulp can never be pressed dry, and the entire amount of juice obtained; for to effect that, every cell of the beet must have been opened by the rasping machine, the bends in the willow twigs and the interstices of the basket-work must be prevented interfering with the pressure upon some parts, and lastly, the substance of the beet must exhibit no adhesion or capillarity towards the juice. These circumstances combined, cause, however, from 15 to 20 per cent of the juice to be left in the pulp, which is extracted in various methods. Some immerse the sacks and residue in water, or allow a stream of water to flow over the opened bags so as to soak into the pulp, which then swells up to its former bulk. The pulp in this state affords other 15 per cent of juice when again submitted to pressure. Others hang the bags in a box exposed to a current of steam as long as the latter is condensed. In this operation care must be taken that the pulp is not boiled, as it cannot then be again pressed. The expressed juice flows down the sides of the pile on to the plate of the press, collects in a gutter which is scooped out all round it, and flows from an aperture through a pipe into the reservoirs.

The tables upon which the bags are spread out are furnished with a similar appendage.

Formerly, with screw-presses, only 65 per cent were obtained of the 95 per cent contained in the beet. One operation under the hydraulic press yields from 70 to 75 per cent of juice; a second operation affords, in all, 85 to 90 per cent: under the most favourable circumstances, therefore, from 6 to 11 per cent of juice, containing from ½ to 1 per cent sugar, are lost in the process.

Pecqueur's press.—It is obvious that the use of Bramah's press is connected with a great deal of manual labour, in filling, arranging, remoistening, and emptying the bags; and any process would be advantageous, which, while effecting an equal amount of work, would obviate this objection. The constant or continuous press of Pecqueur, which has lately been introduced, does away with the necessity for bags, hurdles, and much labour, while at the same time the quality of the juice is injured in a less degree, the operation being effected with less interruption.

The action of Pecqueur's press, a longitudinal and cross-section of which are shown in Figs. 111 and 112, depends chiefly upon the two principal parts; the forcing pump *b*, which communicates the necessary amount of pressure to the beet-pulp, and the straining-

FIG. 111.

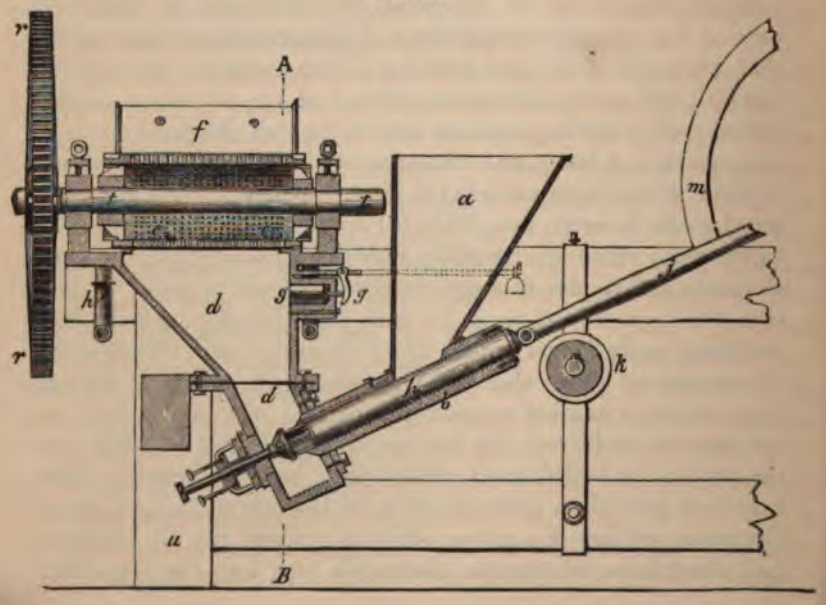
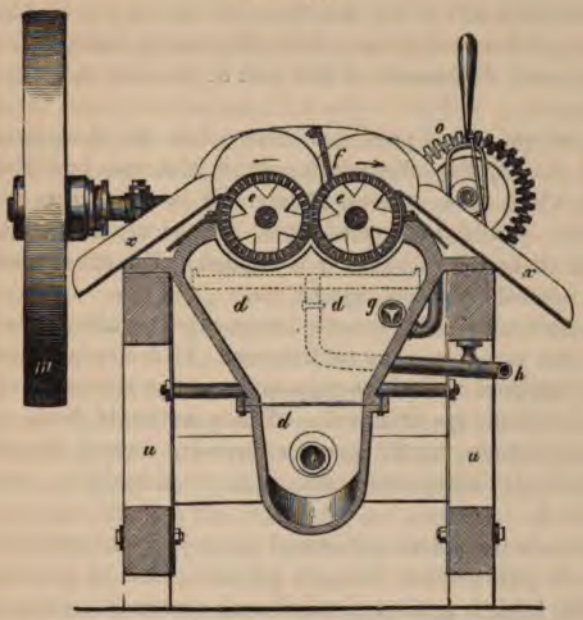


FIG. 112.



drums *e e*, which separate it, under the influence of this pressure, into juice and lees.

The copper funnel *a*, which is kept constantly filled with the beet-pulp during the process, is placed over the pump *b*, into the barrel of which it opens. The roller *m* is set in motion by a driving belt from the motive-power wheel, and communicates this, by means of a curved handle, to the conducting rod *j*, and thus to the piston *h*, which moves backwards and forwards over the friction-wheel *k*. When the piston *h* has attained its highest position, the entire space in the barrel *b*, below it, becomes filled with beet-pulp. The downward motion forces the pulp through the valve *c*, when it is discharged into the cast-iron funnel-shaped vessel *d*, and communicates its pressure to the mass of pulp with which the latter is filled. The vessel *d* is closed on all sides, and the only outlet for the pulp is through the two copper hollow cylinders *e e*. These are perforated on all sides like a sieve, and surrounded by a cylinder of fine wire gauze; they are made to revolve on their axis, at a distance of a few lines from each other, in the direction indicated by the arrows, by means of the toothed-wheel *r*, attached to their axis *t*, which is connected with the drum *m*, by means of the

intermediate wheel *o*. While, therefore, the juice exudes through the sides of the rollers *e e*, and flows off by the pipe *h*, the husks are squeezed between these rollers, thoroughly expressed, carried upwards, and discharged at the side of the iron sides *f*, by the gutters *x*.

That no pulp may pass back from *b* into the pump during the upward motion, the valve *c* is furnished with two powerful spiral springs, which close it immediately. If by any chance too great a pressure should be exerted in *d*, the valve *g* is forced open; and thus all danger of bursting is avoided. The entire machine is erected upon the wooden support *u u*.

The results obtained in practice have not proved altogether favourable to this very ingenious contrivance. It demands a uniformity in the consistence of the beet-pulp, and a certain state of subdivision, which is not always attainable. The quantity of froth or scum which it produces by the peculiar pressure exerted, is still more opposed to its introduction, and is so considerable as scarcely to be obviated.

Pecqueur's press does not extract more juice than the hydraulic press. It yields about 70 or 75 per cent, and 15 per cent more when the husk is again moistened and repressed. From 200 to to 250 hectoliters (4400 to 5600 gallons) can be worked with it in twenty-four hours with a two horse-power; and it is therefore equal to the power of two hydraulic presses.

It is a matter of the greatest importance, and must not be neglected, that all the pieces of apparatus, rasping machines, presses, &c., should be kept perfectly clean, and washed from time to time with lime-water, to correct any acidity that may have been originated in the juice.

The process of maceration.

The method of extracting the juice described in the foregoing pages, by rasping and pressing the beet, is that which has generally been preferred by manufacturers, and is most extensively adopted. It is, however, by no means the only method, nor is it a very perfect one. Besides the necessary interruptions and large amount of manual labour with which it is associated, several other well-grounded objections may be made to it. The first of these consists in the large quantity of juice which is left in the husk, even under the most favourable circumstances; and which, after

the first pressing, amounts to 20 or 25 per cent; and after the second, to 10 or 15 per cent of the fresh beet. Thus, at the very commencement, a very considerable proportion, 11—22 per cent, of the sugar in the beet is lost to the process of manufacture. Although all the manufacturers of sugar, from a knowledge of this fact, connect the feeding of stock with the manufacture of sugar; and the husk makes a very good fodder, when mixed with other kinds; yet this is only a make-shift, and the full value of the sugar in the husk is not by any means realized.

The second objection arises from the well-known action of the nitrogenous substances in the beet, or rather in the juice, which first become of a reddish-brown colour, and then deep black when exposed to the air, and afford a germ for future decomposition and destruction of the sugar, by inducing either the vinous or mucilaginous fermentation. This decomposition ensues the more rapidly the more frequent and abundant the access of air. In the rasping and pressing operations, the finely-divided beet-pulp is brought into the most intimate and frequent contact with the air; first in the rasping machine and its reservoirs, then during its passage to the table, where it is filled into the bags, and subsequently under the press, and on leaving it. In all these operations it is not protected by an atmosphere of steam, as they are carried on in the cold.

A third evil arises from the powerful action of the presses, which causes not only the juice, with all the soluble matters, to be expelled, but likewise a considerable quantity of the finer particles of the pulp.

The endeavour to obviate these evils, which experience and observation have pointed out, has given rise to an entirely new method of extracting the juice, which, although very inappropriately named, is generally known as the *process of maceration*. The same idea lies at the foundation of this process as has been applied in various other branches of manufacture, where soluble salts have to be separated from a mass of insoluble matter, as, for instance, the extraction of the saltpetre earth, wood ashes, crude soda, &c., described in Vol. I. Markgraf was the first to make this suggestion, which was carried out experimentally by Dombasle, and adopted, about the year 1830, by Clemendot, Laurence, and others.

The beetroot, according to Dombasle, was cut into slices, a few lines in thickness, by a machine; and these were hung in baskets

in an equal weight of water, at 75° C. (167° F.) After digesting for half an hour, the liquid had a density of 4° B. (=sp. gr. 1.0294). The beet slices were then replaced by others, and the density of the water raised to 6° B. (=spec. grav. 1.0448). One more charge raised the density to 7° B. (=spec. grav. 1.0526), or that of the juice of the beet, when the infusion was fit for working. The slices of beet once extracted were repeatedly treated with water, and the liquid used, in place of pure water, with fresh slices.

At a later period, in 1841, Dombasle improved his process, and went more systematically to work. He used a boiler, and six wooden exhausting vessels; the water percolates the whole series, one after the other, and is delivered as juice from the last, in a fit state for clarifying. It flows from thence into the copper boiler, where it is boiled. The sliced beet is hung in bags from a crane, into this boiler, containing hot water, for half an hour, when it is removed to the sixth exhausting tub; from thence to the fifth, fourth, third, &c., until it leaves the first exhausted. All these vessels contain water at a temperature of from 20°—30° C. (68° to 86° F). Instead of removing the beet from one vessel to another, the arrangement is sometimes such that a slow stream of water is allowed to pass through the same number of tubs, containing the beet slices. Three other vessels are then necessary; a seventh, for filling; an eighth, for emptying; and a ninth, as a reservoir. The slices in the last vessel are entirely exhausted; in the last but one, nearly so; in the next, not so much exhausted, and so on; until in the first vessel there are only fresh beet slices. When the foremost vessel is exhausted, the water is conducted to the following one, while the former is emptied; and the series is increased by one filled with fresh beet, according to the following scheme:

Fresh water	⟶	1.	2.	3.	4.	5.	6.	⟵	beet slices.				
			2.	3.	4.	5.	6.	7.					
				3.	4.	5.	6.	7.	8.				
					4.	5.	6.	7.	8.	9.			
						5.	6.	7.	8.	9.	1.		
						—	—	—	—	—	—	—	
						—	—	—	—	—	—	—	
							1.	2.	3.	4.	5.	6.	

By this method one condition was always left unfulfilled, and that is, an uninterrupted progress. Much manual labour, caused

by filling and emptying, &c., forms another drawback. With a view to obviate these objections, and establish a continuous process, many suggestions have been made.

Reichenbach's edulcorator.—The edulcorator, or exhausting apparatus of Reichenbach, is a long trough of copper, which, with its lid, forms a close cylinder; the lower semi-cylindrical portion is separated by cross pieces into sixteen chambers; a cylinder passes through the entire length of the trough, in the direction of its axis, and is attached to two perforated shovels for each chamber, in the shape of ploughshares. The apparatus is either placed over the fire, or is surrounded with a covering for the application of steam-heat. The slices of beet fall from a cutting machine into the first compartment, where they remain immersed for half a minute; they are then raised by the shovels of the slowly-revolving cylinder into the neighbouring compartment, and so on through the whole ten, from the last of which they are thrown out exhausted. The water travels in an opposite direction. Into the tenth compartment a current of fresh water is constantly allowed to flow, and passes from thence through an aperture into the ninth, and so on through the entire series, until it passes out of the first, charged with the juice of the beet. During this course it is heated constantly from below, particularly in the first and last compartments, where the fresh beet and the fresh water cause a lowering of the temperature.

It deserves special notice, that the beet, in being passed by the shovels from one compartment to the next, does not come into contact with the air, but with an atmosphere of steam, which fills the entire upper part of the cylinder.

Apparatus of Martin and Champonnois.—Martin and Champonnois chose a totally different mechanism in their apparatus. In a wide tube, of the shape of an inverted syphon, with a cover to admit of steam heat, an endless chain is worked upwards in the one limb, and downwards in the other. At each joint it is furnished with a disc of the diameter of the tube, which form moveable compartments in it. The beet, cut into strips, is forced down on the one side by the motion of the chain, and carried up on the other side, at the end of which it is ejected in an exhausted state. A slow stream of warm water passes in an opposite direction through the tube.

Pelletan's levigator.—The levigator of Pelletan is a gutter or trough, of sheet-iron, separated into twenty-four partitions, similar

to that of Reichenbach. The chambers communicate by channels on the outside, in such a manner that the liquid, from the bottom of the one compartment, passes to the top of the next. The whole apparatus is inclined at an angle of 15°, so that the liquid, poured into the first chamber, flows of itself through the others. In the trough a cylinder is arranged, furnished with twenty-four elements of an archimedian screw, at such distances that each one of these fits exactly into one of the troughs; the water flows in an opposite direction to the pulp, as in all the continuous arrangements. The machine is intended to work with cold water and crushed or rasped beet. The beet-pulp is collected in each compartment by the thread of the screw, which is of perforated sheet-copper, and raised into the next adjoining one. The apertures in these threads are easily stopped up by the beet-pulp, to prevent which, knife-edges are so arranged as to clean these constantly. Before flowing out, the juice passes through a partition of wire-gauze, which filters it.

If the method of maceration, or, more properly, of lixiviation, had the advantage, as was expected, of extracting and dissolving in the liquid the *entire* amount of sugar contained in the beet, without leaving any in the husk, this would be a decided advantage. That this aim may be approached, is as obvious as that it can never be entirely attained. The cells of the bulb are ruptured in this process, either by a grater as when the press was used, and the beet-pulp is then lixiviated with water, or it is effected by the treatment with hot water, when the cells of the cut slices of beet are burst by the expansion of the liquid within them. Complete exhaustion can consequently only be attained when literally all the cells are burst, and this is a practical impossibility. Judging from the results that have been made known, the produce is not greater than when the presses are used. In a French factory (belonging to Mesmay), for instance, it was even less; an average quantity of 95 per cent of the weight of the beet was obtained in liquid, while there should have been 115 per cent of liquid, to correspond with 85 per cent of expressed juice. Even if more had been obtained than by the presses, this advantage would be gained at a considerable sacrifice. In the process of maceration, the manufacturer has added the water used for lixiviation to the very considerable amount of water in the beet, which has all again to be evaporated. This additional quantity of water demands the consumption of a larger quantity of fuel. The

saccharine liquid operated upon is, according to the advocates of the process of maceration, always of the same specific gravity (containing the same amount of sugar) as the natural juice—for instance, 7^0 B. (=spec. grav. 1.0526). We must not, however, be led by this into error. Suppose an equal amount of beet slices and water are employed, and the beet contained 0.9 parts of juice, with 0.1 of sugar, its juice therefore 11.11 per cent, which is a mean quantity, and that the same lixiviating water was successively employed upon n portions of beet, the liquid will then contain $=\frac{10\,n}{0.9\,n+1}$ per cent of sugar. Whence, by calculation, the sugar dissolved in the lixiviating water, after the first treatment, will =5.26; after the second, =7.14; after the third, =8.1; after the fourth, =8.7; after the fifth, =9.3; after the sixth, =9.9; after the twentieth, =10.5; and only after the one hundred and tenth treatment, =11.0 per cent; and therefore, in a practical point of view, a quantity almost absolutely equal to that in the original juice. The water thus vanishes only with reference to the figures, and even then not entirely, but is not the less present in the evaporating pans of the manufacturer. If the latter, in accordance with the above supposition, macerates 10 cwts. of beet in water, he obtains 1 cwt. of water; and when he annually works up 40,000 cwts. of beet, he has 4,000 cwts. of water more than is contained in the beet to evaporate, however much the figures may tend to deceive him.

It is also obvious, that the specific gravity of the lixiviating water increases rapidly at first, but very slowly afterwards, and can, in point of fact, never attain the strength of the natural juice.

After the sixth treatment, the specific gravity indicates too small a quantity by 1 per cent; and when the hydrometer indicates an equal degree of concentration to that of the natural juice, this only proves that other substances besides sugar have been dissolved, and raised its density.

These remarks apply with equal force to the processes of uninterrupted lixiviation, like Reichenbach's, Martin and Champonnois', or Pelletan's; with this difference, however, that in these the dilution of the juice is less, in proportion as the number of compartments in the apparatus is increased.

Another consequence of the lixiviating process is worthy of notice, this is, its effect upon the chemical nature of the juice.

If the flesh of the beet is steeped for some time in water, at a temperature of 60° C. (140° F.), as is prescribed by most of these methods, the cells are not only partially opened, and the structure destroyed, but the albumen in the cells themselves is coagulated, and only partially passes into the solution, retaining in the coagulum several other substances which are prejudicial to the production of sugar. A much purer juice is consequently obtained than is possible when the fleshy part and the cells are disintegrated by powerful mechanical agencies.

The nitrogenous matters that are not coagulated by heat, and which blacken by exposure to air, and induce decomposition in the juice, have much less opportunity in the heating process to come into contact with the atmosphere; and in Reichenbach's process, air is almost totally excluded, the whole apparatus and the beet-pulp being enveloped with water, or an atmosphere of steam.

The favourable conditions connected with warm lixiviation are limited to a temperature just sufficient to burst the cells and coagulate the albumen; the same results follow a longer or more powerful application of heat, as, when the beet is boiled, the substance of the cellular tissue is then so softened that the whole becomes pasty, and hinders the evaporation of the liquid from the solid parts, under which circumstances, the juice is less pure, and more prone to decomposition than that expressed in the ordinary manner. Another circumstance favours this; the vegetable gelatin is not soluble in the natural juice, but is soluble in pure water; it consequently remains in the husk when the presses are employed, but accompanies the sugar in the process of maceration. The coagulation of the albumen is not needed when a cold lixiviation is practised.

It must also be noticed, that the residue or the beet husk is deteriorated more or less in quality, and lessened in quantity, and its value consequently diminished as fodder for cattle. These residues are perfectly insipid, and are obtained more saturated with water, or in a condition in which they cannot be preserved, unless pressed or dried artificially.

In the best maceration machines, the beet requires at least six hours for thorough lixiviation. An accurate separation of the successive portions of juice is difficult of execution on a large scale, for which reason the juice is kept partly for a longer time in the apparatus than should be, and is exposed to the chances of fermen-

tation which it often undergoes, and then places the entire quantity in the same condition. This objection is not one of the least important that are urged against the process of maceration.

At first, the process of maceration was very generally adopted, but experience has proved, by returning to the older methods, that its advantages are not sufficient to counterbalance the objections to it.

d.) The clarification of the juice.

Preliminary remarks.—It is obvious, from the method of extracting the juice, that this is not simply a solution of sugar in water, but a solution of all the soluble constituents of the beet, both organic and inorganic. The fresh, unaltered juice possesses a weak, sometimes nearly imperceptible acid reaction, and contains indeed all the substances mentioned at page 340, excepting the cellular matter, inasmuch as this has not passed over mechanically into the juice. The fatty and chlorophyl-like matters are held in suspension, the others in solution. The acid character of the juice enables it to dissolve the phosphates of the earths.

Two classes of constituents in the juice are the great obstacles to the production of crystallizable, marketable sugar, and these are *the nitrogenous and saline matters.* These are never absent in the juice, and although the albumen may be altogether or almost entirely removed by a hot process of maceration, the other three or four substances of the same class remain, and these are the most objectionable.

The nitrogenous substances in the juice are the source of so much injury, on account of their changeable nature, producing decomposition in the substance of the juice itself, inducing acidity, which speedily converts cane- into grape-sugar, which latter is of a much less stable character than cane-sugar. These objectionable transformations go on in the cold, but are much promoted by heat. At the boiling-point, the alkaline character of the juice, which cannot be avoided in the subsequent operations, likewise gives rise to the evolution of ammonia from these nitrogenous matters. The salts, when present only to the amount of 2 per cent in the juice, either obstruct or prevent the crystallization; and they are indirectly objectionable, when their bases are alkaline and become free during clarification.

All these influences are conjointly sufficient to destroy, for the

greater part the cane-sugar as such, before the point of crystallization is attained; and for this reason it is absolutely necessary to remove them before concentrating the juice. *Clarification* or *defecation* effects this. Its object is, firstly, to render the foreign matters insoluble, particularly those belonging to the two classes named, to precipitate them chemically, and separate them in a mechanical manner by decantation. Of all the suitable and economical agents, none is so well adapted to precipitate so many of the foreign matters at once as caustic lime. For this reason, milk of lime is preferred to any other substance in the ordinary processes of clarification; although this has in some measure been superseded by barytes, suggested by Dubrunfaut. The application of lime in the clarifying process, without other agencies than a boiling temperature, has been imported from the colonies into Europe.

The clarification may therefore be defined as the separation of all those substances from the juice, which are precipitated by lime and a boiling temperature. It must be observed, however, that lime only separates the greater number, and not the whole of the organic matters; for basic acetate of lead produces another precipitate after the application of lime, and nitrate of mercury forms a further precipitate after the removal of that produced by acetate of lead. Thus, in two experiments with different varieties of beet, Hochstetter found:

Ingredients of the juice.	1 Exp. in 100 parts of juice of 9° B. (=sp. gr. 1.064).	2 Exp. in 100 parts of juice of 9°.5 B. (=sp.gr. 1.069).	Mean, in 100 parts of the solid residue of juice.
Foreign organic matters precipitated by lime . .	1.003	0.914	7.75
Foreign organic matters precipitated by acetate of lead	0.092	0.116	0.84
Foreign organic matters precipitated by nitrate of mercury	?	?	?
Salts and saline bases . .	—	—	6.48
Sugar	—	—	84.93
			100.00

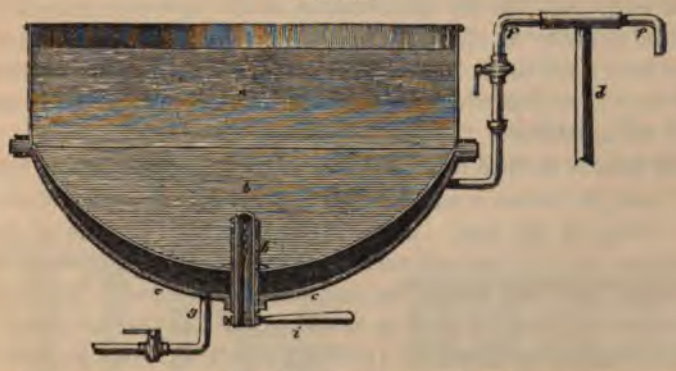
When a clarifying pan has a capacity of 2000 lbs. of juice, as is usually the case, it will contain, according to the above data, the amount of sugar in the beet being calculated at 10 per cent:

Sugar	208 lbs.
Organic matter precipitated by lime .	19 „
Organic matter precipitated by acetate of lead	2 „
Salts and bases	16 „
Water	1755 „
	2000 lbs.

The quantity of foreign matters to be separated at each operation is therefore very important.

The clarifying pan.—In clarifying, it is of importance to heat the juice rapidly to the boiling-point, without burning, particularly when the precipitate has been formed, and to be able to separate the deposit easily from the clear liquid. Steam heat has been universally adopted for securing the first, and a special decantation-cock has been invented for the second, object.

FIG. 113.



The clarifying pan, Fig. 113, is constructed of sheet copper. The cylindrical portion *a* is fixed to the lower part *b*, which is in the form of a segment of a circle, by means of flanges and screws. The bottom is surrounded by a cast-iron jacket, between which and the pan the steam is introduced; the steam enters by the pipe *d* and *f*, while the spent vapours and condensed water are drawn off by the pipe *g*. The decanting cock is constructed of a strong case, fitted into the two bottoms, with a cock and handle *g* attached to it; both are perforated with apertures, one above the other, Fig. 114. In the cask itself these apertures are placed perpendicularly, one above the other; in the case, on

FIG. 114.

the contrary, each upper aperture is placed at an arc of 99° from the lower. By this arrangement only one aperture of the cock can face at the same time the corresponding aperture in the case; if, for instance, the position of the two is such that the upper apertures face each other, and are open, when the cock is turned ¼th of a circle, the middle aperture is closed; if it be turned ½ round the third, and if ¾ths round, all three apertures are closed at once. By simply turning the cock, therefore, the liquid may be drawn from two different levels in the pan, and lastly from the bottom.

The nature of the juice is such, that it sometimes requires a larger, at others a smaller, quantity of lime for clarification. It is therefore only prudent to slake at once a sufficiency of lime for the entire quantity of sugar to be worked. The requisite quantity of lime, made up with water into milk of lime, is determined each time by a preliminary experiment. It is necessary that the test be made about once every week, as the deterioration of the juice requires an increased quantity of clarifying material. The requisite amount of lime must likewise be determined for each different kind of beet, and for the produce from different soils. The clarification is carried out as follows:

As soon as the pan is about ⅓rd filled with the juice coming from the press, the steam is admitted, so that the heat is applied during the filling of the pan. Time is thus saved, which is of importance, as it is a general rule to wait for the coagulation of the albumen, and this cannot be too much accelerated. In many factories the juice is heated up to 55° or 60° C. (131° to 140° F.), and in some even to 80° C. (176° F.) In both cases a scum is formed; this is skimmed to one side, and the entire quantity of milk of lime added, and well stirred up with a wooden mashing-stick. Flocculent particles immediately make their appearance, which come to the surface, and there form a dirty-greyish skin. It is soon observed that the effect of the increasing heat is to cause the scum to break up in the centre, and collect at the sides; the boiling commences at the sides in one or two points at first, but soon spreads to all parts, and thorough ebullition ensues. The admission of steam is then continued, according as the albumen separates. When the whole is thoroughly boiled up, the steam is shut off, and the contents of the pan are allowed to settle during ten minutes.

The liquid evolves ammonia during the process of clarification;

at the end of the process, the dirty mass of froth must be thick and tough, like cheese-curd, and fissured in all directions. A specimen of the clarified liquor must be of a clear wine-yellow colour, in which the precipitated matters swim as distinctly separated and easily-deposited flocks.

It is a bad sign when the ebullition does not commence at the sides, but only in the middle of the liquid.

Even in a successful process of clarification, an excess of lime is always dissolved in the juice; and this is easily observed in a specimen exposed to the air, or breathed upon, when it becomes covered with a thin skin of carbonate of lime. The success of the subsequent operations is very much dependent upon the amount of this excess, which must necessarily be always present. No rules can, however, be laid down concerning it, as the amount varies with the nature of the juice, and experience is the only guide in preserving a mean between too much and too little.

At the expiration of ten minutes, the clarified juice is allowed to flow off through the cock *i*; at first, through the upper aperture, then through the middle to the evaporating pans, or direct to the filters. The deposit, which cannot be very bulky, is run off from the lowest aperture to the bag-filters, Fig. 115. The square apertures in the frame, Fig. 116, form the mouths of

FIG. 115.

FIG. 116.

the filters; the liquor that flows through collects in a tinned gutter, the residue is expressed, and afterwards employed as good manure. Much lime is deposited in the fibres of the bags, so that after some time they become quite hard, and require consequently to be boiled every twenty-four hours with dilute nitric acid, and well washed.

Chemistry of clarification.—The numerous ingredients which, during the clarification of the juice, are acted on by the lime and the boiling temperature, render the chemical processes very complicated. A review of these changes is simplified by considering them separately.

When the juice to be clarified has attained a temperature of 60°—70° (140°—158° F.), the albumen coagulates, and carries with it all the impurities to the surface; with bad, more or less spoiled, beet, (particularly when it has germinated,) an exceptional case occurs, and the albumen is converted, at the very commencement, into compounds of a different character. The juice does not then coagulate (Braconnot). In this case, and at too low a temperature, or with imperfect coagulation, the albumen in solution, or the product resulting from it, is precipitated by the lime. The same occurs with the changed albumen and the nitrogenous substance resembling gelatin.

The other nitrogenous matters, particularly the easily-oxidised substance, which gives rise to the colouring and blackening of the juice, remain in solution. The free acids—pectinic, malic, and oxalic, the acid salts of the juice—are neutralized by the lime; and as a direct consequence of this, all the salts held in solution by the free acid of the juice, as the phosphates and malates of the earths, are precipitated; while decomposition of all the neutral salts that are decomposable by lime ensues, and malate, oxalate, and pectinate of lime are precipitated, the bases originally in combination with these acids (protoxide of iron, protoxide of manganese, alumina, magnesia, &c.) accompanying the precipitate, when they themselves are insoluble, the alkalies remaining dissolved. The reaction of the juice consequently becomes alkaline, which is augmented by the excess of lime dissolved by the sugar. The precipitate of the earths and earthy salts carries with it a great part of the colouring matter, and the liquid becomes of a lighter colour.

The juice being kept meantime at the boiling temperature, the liberated alkalies exert an action on those nitrogenous matters which are neither precipitated by lime nor a boiling temperature.

The precipitates from the clarifying pans of the manufactory of M. Schmidt, in Magdeburg, have been examined by Hochstetter, who dissolved them in acetic acid. They were found composed of:

Albumen.

Nitrogenous substance, resembling gelatin.

Nitrogenous substance, resembling humus (a product of the action of the acids and alkalies of the juice upon the original compounds of this class).

A combination of lime with fat or a *lime-soap.*

Oxalate of lime.

Phosphate of lime.

Sand and *foreign matters* added with the milk of lime.

In beetroot that has sprouted, or the juice from which has become deteriorated in quality by keeping, the acid reaction is stronger, more or less cane- is converted into grape-sugar; albumen, and the nitrogenous matter which passes into the black substance by exposure to air have been changed into such as are precipitated by lime, and a double quantity of lime is therefore often requisite for such juice.

Different methods of clarifying.—The practical operations just detailed constitute the method of clarification now generally approved by the best manufacturers, and may be considered as the one usually adopted. It is supported by experience, and based on scientific principles and views, which have only latterly been generally acknowledged. Although manufacturers have been agreed upon the fact of the diminution of the cane-sugar in the juice during the operation of clarifying, evaporating, boiling, &c., very different opinions have been held in different places at different times as to which of the injurious agencies was the actual cause of this diminution, and in what manner it could best be remedied. Sometimes the alkaline character of the clarified juice, sometimes the salts of ammonia, were viewed as the grand obstacles to be overcome, and to remedy these, changes in the process have been made in all directions, real advantages and disadvantages being often over-estimated. A series of new methods of clarification have thus been called into existence, only a few of which have stood the test of experience, and are of more importance. It is remarkable, that in all that has been done to improve the methods of clarification, so little attention has been paid to the *principal* point, or to the nitrogenous albuminous principles in the juice. The question can only receive a rational answer, when put in the manner proposed by Hochstetter; for it cannot be denied that the properties of the juice with which the manufacturer has to contend are all connected with the albuminous constituents. It is

equally certain that the study of these can alone afford a safe guide to the practical man, and yet how very imperfect is our knowledge concerning them.

Method of the colonies.—We have yet to characterize those means and methods of clarification, which, together with the process already described, and which is usually known as the *colonial process*, were or are still of special interest.

Opposed to the *process of the colonies* are those processes in which the lime is removed by *an acid.* It was considered necessary to neutralize the alkaline juice, partly from not knowing intimately the action of lime on cane-sugar, and by confounding it with the action on grape-sugar, and over-rating its action generally; partly from ignorance of the properties of animal charcoal, partly from fear that the excess of lime might exert an injurious action in dissolving the precipitated albuminous matters, and partly on account of the low price of acid compared with an amount of animal charcoal equal in effective value.

Although, in conformity with these ill-founded fears, a perfectly neutral juice is certainly the best suited to the operations of the sugar manufacturer; yet the very perfect neutralization here presumed is practically an exceedingly difficult, if not impossible, operation. If the juice remained alkaline, the object is not attained; and if the opposite or an acid reaction ensues, in place of a minor evil, a very serious one has been created; for, even in a highly diluted state, the acids speedily convert cane- into grape-sugar, at the boiling temperature; and this is the worst evil that could possibly occur.

French process.—In the process known as the older French process, sulphuric acid is added to the juice, after it is separated from the deposit formed on the application of lime. There are, however, difficulties in fixing upon the precise period when the acid should be added. If the acid is added immediately, and the alkaline reaction at once concentrated, the juice will contain, in place of caustic potash, neutral sulphate of potash, and (as at this period the action of the lime and alkali upon the albuminous matters has already commenced) sulphate of ammonia instead of ammonia. The latter loses ammonia upon evaporation, and the juice becomes acid. With an excess of sulphuric acid the same result obtains. A free acid has the same action upon the nitrogenous bodies as free alkali; ammonia is evolved, converted into an ammoniacal salt, which is then decomposed in the same manner.

Practical men prefer consequently to evaporate the juice, until the evolution of ammonia has ceased, and then to add sulphuric acid, in that case only when the juice is very alkaline. Others add the acid immediately, but only in sufficient quantity as just to saturate the alkali in order that the free ammonia may evaporate. This is more a theoretical than a practical measure.

In any case, gypsum is produced, which is deposited in consequence of its difficult solubility in proportion as the juice is concentrated, and thus becomes troublesome. The total amount of saline matter is increased and augmented in the syrup, and this is far less easily absorbed by the animal charcoal than free bases or acids.

German process.—The process, known as the *German method of clarification*, is that proposed by Achard, improved by Kodweiss, and chiefly practised in Bohemia, while it has been abandoned in most other countries. Its characteristic feature consists in treating the juice with sulphuric acid, before the application of lime.

The observation which led to this practice was, that the juice, treated with sulphuric acid fresh from the press, does not blacken, *i. e.* the acid prevents the oxidation of the nitrogenous matters. The acid, therefore, which with good juice is applied in quantities of $\frac{3}{1000}$th parts, or with ill-conditioned juice in $\frac{4-5}{1000}$ths has a preservative action, and occasions simultaneously the coagulation of the albumen, although gelatinous, acids are separated by it. No advantage is gained by this practice to compensate for the disadvantages already enumerated as accruing from it, and to which must be added the inferior grain of the sugar thus treated.

The uncertainty attending the use of a strong mineral acid, like sulphuric acid, can be avoided, with all its injurious consequences, by using carbonic acid, as lately proposed by Kuhlmann. Carbonic acid precipitates lime most completely from warm solutions of sugar, without rendering the liquid acid. It is a very cheap material, particularly when produced by the combustion of coal or coke; and its application demands no special amount of dexterity. This acid would certainly have been adopted as a means of saving animal charcoal, if its production and stowage did not require complicated apparatus in the shape of conducting-pipes, gasometers, &c.

Besides lime and acids, several salts have been proposed as a third class of clarifying agents.

Clarification with gypsum.—Brande recommends the addition

of 1¼ lbs. of gypsum to every 100 parts of juice, at the boiling temperature; the clarified juice is then to be filtered through woollen cloth, and treated with lime in a subsequent operation.

It is well known that gypsum precipitates albumen and similar substances, which are only held in solution by means of alkalies (p. 42), and many other alkaline salts are also decomposed. As the lime, however, cannot be dispensed with, no real benefit is derived from the use of gypsum.

Alum and sulphate of alumina. — Bouché recently proposed treating the juice with 1.5 per thousand of alum, and subsequently boiling with lime. The application of alum upon the plan patented by Howard in 1812 is however much better; according to which a solution of alum is precipitated by a sufficient quantity of milk of lime; the precipitate, separated from the sulphate of the alkali by decantation, and straining through linen, forms the clarifying material or finings. It consists, on the one hand, of an excess of lime and gypsum, which act in the manner before described; and, on the other, of alumina, which is precipitated in combination with organic, chiefly colouring, matters. The alum might of course now be replaced by sulphate of alumina. This very rational process of clarification has been rarely adopted, perhaps because alumina (like oxide of iron) is not rendered quite insoluble in saccharine solutions by lime.

Some few other proposals may here be noticed, which have for their object the separation of the excess of lime, after the ordinary clarification, like that of Kuhlmann with carbonic acid.

With other salts of alumina.—Acar employs pectinic acid, prepared upon the plan of Braconnot; Thomas and Delisse propose oxalic acid; Mialhe, the oxalate, Mallet, the tartrate of alumina. The oxalic, pectinic, and tartaric acids form with the lime insoluble salts, which are precipitated with the alumina, which carries down organic and other colouring matters with it. The presence of free alkali, however, is liable in some degree to counteract this result. The high price of these salts has at present precluded their application on an extensive scale. Wilson proposed sulphate of zinc with the same object in view; Decock, tannic acid, which, it is well known, forms insoluble compounds with most albuminous matters.

e.) *Evaporation of the clarified juice.*

It would be a great step gained if the juice of the beet could be completely separated from all foreign matters during the clarification. That this is not possible has been shown at page 370. The juice contains, after clarification, besides crystallizable sugar:

A portion of the nitrogenous substances, particularly those that are easily oxidized, and blacken when exposed to the air; *lime,* partly combined with acids to form soluble salts, partly as a combination of sugar and lime; *potash, soda, ammonia, magnesia* (?), as *chlorides, sulphates,* and *nitrates; grape sugar,* and the *colouring matters* produced by its decomposition, inasmuch as they are acid, and in combination with the above-mentioned bases.

The relative quantities in which these substances are present depend much upon the kind of beet, but more upon the good or bad condition of the bulbs, and the time that they have been kept. This is especially the case with the nitrogenous matters which remain unprecipitated in much greater quantity after the addition of lime, when the juice has become much injured by keeping.

Schatten, who investigated the amount of lime in the clarified juice, found in ten different specimens:

Nos.	100 parts of juice contain lime (CaO.)		
	As lime in combination with sugar.	As lime-salts.	Total, in both together.
1.	—	—	0.202 parts.
2.	—	—	0.203 „
3.	—	—	0.158 „
4.	0.229 parts.	0.083 parts.	0.312 „
5.	0.098 „	0.070 „	0.168 „
6.	0.130 „	0.049 „	0.179 „
7.	0.084 „	0.085 „	0.169 „
8.	0.096 „	0.050 „	0.146 „
9.	0.085 „	0.085 „	0.170 „
10.	0.108 „	0.084 „	0.192 „

After each process of clarification there remain therefore in the pan (for every 2000 lbs. of juice) $1\frac{1}{2}$ to $4\frac{1}{2}$ lbs. of lime in combination with sugar, or $2\frac{1}{2}$ to 6 lbs. of lime in all. In the plans at present adopted by most makers, no special measures are taken to remove the lime from the clarified juice; but this is effected

by the charcoal, which must be used to separate the colouring matter.

The following results of observation determine the method for the evaporation and filtration of the juice.

If solutions of pure cane-sugar in pure water, even when highly concentrated, for instance, of 25° B. (=sp. gr. 1.21), containing 45 per cent of sugar, are boiled as long as the evaporation and boiling usually lasts on a manufacturing scale, or from one to two hours, no appreciable amount of colour is developed, but traces of uncrystallizable sugar are formed. This change is much more apparent when the boiling is carried on in close cylindrical vessels than when in open shallow basins. When the air has access to the boiling liquid, or when the current of air is passed through the liquid at the boiling temperature, a still more perceptible decomposition ensues, which is made apparent by a high degree of colour (Hochstetter). Soubeiran states, that a saccharine solution, changed in this manner by boiling, reddens blue litmus paper. According to Hochstetter, this is not the case, but the alkalies become saturated, and lose their alkaline reaction. In either case, acids are amongst the products of decomposition which convert cane- into grape-sugar, and thus occasion a progressive *acceleration of the transformation of cane-sugar*. If nitrogenous substances are present simultaneously with the sugar, these are decomposed at the boiling temperature of the solution, and exert an accelerating action upon the decomposition. In the presence of lime, the decomposition of these matters proceeds, without however communicating the change to the cane-sugar. The lime, in this case, protects the cane-sugar, the nitrogenous matters being decomposed in the presence of this base into ammonia, which is constantly evolved, and into acids, which immediately combine with the lime, become saturated, and their injurious action upon the sugar is thus prevented. In fact, the precipitates deposited in the pans during evaporation consist chiefly of combinations of lime with the products of decomposition of the nitrogenous matters. One essential condition for the production of the precipitates is a temperature above that of boiling water. In the vacuum-pan, or in a partially-exhausted vessel, they are not deposited.

If clarified beet-juice contain nothing but sugar, nitrogenous matters and lime, the phenomena above described constantly occur; if, on the other hand, it contains also grape-sugar, as it

usually does, either from the bad quality of the juice, or produced during clarification, the result is more decidedly prejudicial to the purity of the juice; grape-sugar being decomposed the more readily by alkalies or lime, the higher the temperature, and very rapidly at the boiling temperature, colouring the juice of a very deep hue. The grape-sugar and the lime, as such disappear almost simultaneously, the alkaline reaction is constantly on the decrease, while brown compounds between the products of decomposition of the grape-sugar (glucic acid) and lime are formed. From these partially-soluble compounds the lime cannot be precipitated by carbonic acid. The worse the quality of the juice, therefore, the more it will lose its alkalinity by evaporation, in consequence of the increased quantity of grape-sugar and nitrogenous matters. Cane-sugar does not share the decomposition of grape-sugar as long as uncombined lime (alkali) is present. This decomposition is only injurious, although it is so in a high degree, on account of the juice becoming deeply coloured, and the uncrystallizable foreign matters which impede the crystallization of the sugar being increased in quantity (Hochstetter).

These observations show, therefore, that during the evaporation of the juice, the cane-sugar is not changed as long as the liquid is alkaline. They also indicate, however, that during boiling, although the cane-sugar remains unchanged, there are partly precipitates, partly coloured products formed, which are increased, not only by the concentration itself, but also by the constant chemical action; and that lastly, colourless compounds, as salts, combinations of lime with sugar, &c., are present, which render the crystallization so much the more difficult, as they have relatively increased in bulk with the diminution of volume by evaporation. It is easily calculated that the uncombined lime in the clarified juice must have been augmented to nearly 1 per cent by evaporation to the point of crystallization, and the soluble salts to nearly 3 per cent. It is, therefore, of the utmost importance to separate these matters from the juice as much as possible, between the periods of clarification and crystallization. This is effected by *animal charcoal*.* This substance possesses the property of condensing, on the surface of its pores, the different substances dissolved in a liquid, thus rendering them insoluble, and separating them. If a liquid like cla-

* Formerly ox-blood was used, as in the refinery of colonial sugar, p. 317).

rified beet-juice contain comparatively a large quantity of sugar, and only small quantities of colouring matters, lime and salts, these latter are completely absorbed by the charcoal, while the amount of sugar is scarcely perceptibly lessened. (See Appendix "Animal Charcoal.")

If the beet-juice were of the same quality in all places, there would hardly be any difference in the modes of carrying out the following operations in the different factories. The quality is, however, extremely variable, so that on this account, and from the different methods of clarification, from the views which are entertained respecting the character and reaction of the juice, the development and progress of these views, and also in consequence of old customs and new prejudices, the two operations, and the manner in which the one follows the other, have at different times, and at different places, been, and are still, very differently managed.

Formerly, when the colour and turbidity of the juice were generally attributed to the temperature employed in evaporation, rather than to the foreign ingredients left after clarification, the clarified juice was evaporated at once, until those signs showed themselves, when the liquid was immediately filtered through animal charcoal, and evaporated to the point of crystallization. Before filtering, and during evaporation, some have found it necessary, after the evolution of ammonia has ceased, to neutralize partly, but not altogether, the free alkali with sulphuric acid. (This is practised in Bohemia.) The disadvantages of this practice, which arose from the erroneous idea that the alkalies exerted a very prejudical action upon the sugar, have already been adverted to above. They are equally prominent where phosphoric acid, a very expensive substitute, is employed in place of sulphuric acid. Other manufacturers (the French) preferred using a much more rational means for removing the free alkali, which consisted in sprinkling the dust that falls from animal charcoal, when pulverized, into the evaporating pans.

More preventive measures are now adopted, and attempts are made, not only to remedy the changes in the sugar after they have occurred, but likewise to preclude their occurrence, guided by the idea that the profit and amount of produce are greater the fewer foreign matters remain in solution during the concentration, evaporation and boiling of the juice; and that the lessening of the quantity of these is not bought too dearly at the cost of an addi-

tional quantity of animal charcoal. Every exertion is made to bring the juice into the pan as pure as the circumstances will permit; and it has been discovered that free alkali, or lime, does not affect cane-sugar, but rather tends to prevent its decomposition; the alkalinity of the juice is retained as long as is compatible with the absence of free bases in the finished article, the taste of which they impair. The uncombined bases are separated by animal charcoal. If the juice could be filtered immediately before crystallization, that operation would be postponed to that stage of the process; but the crystallizable syrup is much too thick to be passed through the filters, without great loss of time, and other inconveniences. The separation of the bases, by means of the charcoal filters, cannot consequently be so long deferred, and must be completed shortly before the period at which the juice ceases to be easily filtered. The modern process, now universally adopted (totally different from the more ancient), may be seen from the following scheme, which includes all the operations between the clarifying and crystallizing processes:

Direct filtration of the clarified juice through animal charcoal.
Evaporation of the once filtered juice.
Second filtration through animal charcoal.
Boiling the juice to the point of crystallization.

We shall first describe the arrangement of the pans and filters.

The Boiling Pans.

All the transformations to which sugar is subject, and which are not prevented, if indeed they are not induced, by clarification, are developed during the entire process of concentrating the juice, *i. e.* during the entire period that the sugar is subjected to a higher temperature. They occur the more readily, the higher the temperature and the longer its duration. The temperatures at which solutions of sugar, of different degrees of concentration, boil, do not in themselves materially alter the character of the sugar, but they are of essential aid to those substances which induce change, particularly when an insufficient quantity of alkali is present. Although, as a general rule, it is correct that the sugar is least affected when the evaporation proceeds quickly, and at a low temperature, yet the very exaggerated opinions held respecting the prejudicial effects of these

agencies, have led to the idea that, by improved boiling apparatus, more crystallizable sugar could be preserved from destruction than by any other methods of procedure. The ingenuity of those acquainted with the subject has consequently been turned, for a series of years, to solve that problem; and so numerous have been the patented inventions, that it is scarcely possible to review them all. The space allotted us in this volume, and the fear of tiring our readers, precludes the possibility of noticing fully all these inventions. We shall, therefore, endeavour to describe shortly, but accurately, the principles upon which those improvements were based which have only enjoyed a temporary importance, and enter more fully upon such few as have proved themselves of lasting value.

Principles upon which the pans are constructed.—In the arrangement of all sugar pans, the great objects are saving of time, lowering the boiling temperature of the juice, economy of fuel, and lastly, a safe and easy execution of the operations. The different modifications may be classified in the following manner:

1. *Evaporation under Atmospheric Pressure.*

A. Heat applied by an open fire.
  a) Fixed or stationary pans.
  b) Swinging pans.
B. Heat applied by high pressure steam.
  a) Interrupted or periodic operations.
  b) Uninterrupted operation.
  c) Evaporation accelerated by passing hot air through the liquid.

2. *Vacuum pans—Boiling the Juice under diminished pressure. Heat applied by Steam.*

A. Vacuum produced by an air-pump.
B. Vacuum produced by a Torricellian tube.
C. Vacuum produced by a jet of steam.
  a) Periodically working apparatus.
  b) Uninterruptedly working apparatus.

Pans over an Open Fire under Atmospheric Pressure.

The solubility of most of the metallic oxides in the saccharine liquid renders it necessary to construct the pans of a metal that is

not easily rusted. Copper is generally used for the purpose, and must be kept perfectly bright and clean. The same pan may be used for evaporating and boiling.

The old-fashioned stationary pans over an open fire were subject to two objections. With an open fire, it is difficult to prevent that portion of the pan not covered with the saccharine solution from becoming over-heated; if during ebullition or by spirting, portions of sugar come into contact with the hot part of the pan, they become converted into caromel, and then communicate a brown colour and bitter taste to the juice. It is, also, difficult to empty the pan, and impossible to do it thoroughly; the fire must consequently be extinguished after every operation, to prevent the residue from being burnt.

Swinging pans.—The swinging pans (Fig. 117) admit of the juice being more easily removed, as they are furnished with a lip, and are moveable on an axis at the point where the lip comes in contact with the brick-work; they are raised when required to be emptied by a pulley, and thus removed at the same time from the fire.

FIG. 117.

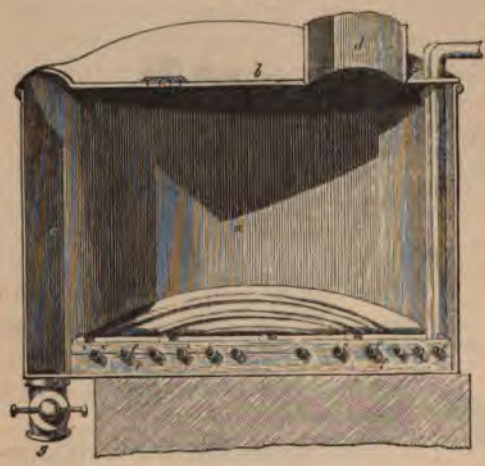
Contrivances have also been introduced to accelerate evaporation by increasing the extent of surface of the boiling juice. Gadesden applied a roller, revolving slowly, and dipping somewhat below the surface of the liquid, by which means a thin layer of hot juice was raised above the level of the remainder, and exposed to the air.

Pans heated by High Pressure Steam under Atmospheric Pressure.

It is obvious that all danger of burning is at once avoided by so heating the pan, that its temperature at no part exceeds the boiling-point of the saccharine liquid. This can only be secured by the application of steam heat. Achard first conceived the idea of applying steam, but he failed in the execution, by using steam at the ordinary pressure, and thus prolonged to an unnecessary

extent the process of concentration. What was gained by a uniform application of heat and a lower temperature, was altogether vitiated by the loss of time. A solution like the saccharine juice boils at a temperature considerably above the boiling-point of water; it is consequently necessary to employ high pressure steam, which not only evaporates, but boils the liquid, when the operations are to be speedily completed.

FIG. 118.



All the pans heated by steam are therefore supplied from a boiler, constructed to produce steam of the proper pressure.

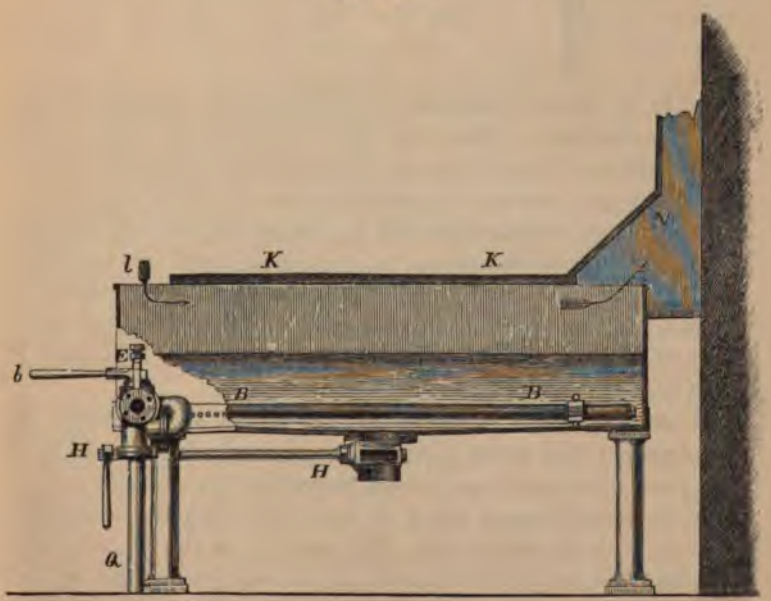
Halette's Pan. — In Halette's pan (Figs. 118 and 119), the steam is applied by a double spiral pipe at the bottom, in such a manner that the steam enters by the one, and is evolved by the other spiral. The temperature at the bottom of the pan is thus rendered almost perfectly uniform, the hottest portions of the delivering pipe being placed by the side of the coldest part of the exit tube. The admission of steam is regulated by a cock; a second larger cock *g* is used for withdrawing the evaporated juice. By covering the pan *b*, a proper ventilation is established, the steam collecting from the juice being conveyed by a pipe *d* to heat the drying chambers. The arrangement

FIG. 119.

must be such, that none of the condensed vapour is returned to the pan. Halette's pan is 4½ feet in diameter, by 3 feet deep. The steam is at a pressure of two or three atmospheres, and has consequently a temperature of 121° to 135° C. (250° to 275° F.) The spirals can be removed while the pan is cleaned. Two of these pans are generally placed side by side, that the whole amount of one process of clarification may be worked at once, and the juice not stand above 8 inches deep in each pan. The boiling commences at the bottom, and the temperature of the liquid is of course raised with the height of the column of liquid.

Taylor's Pan.—To diminish this height still more, large quadrangular pans, of similar construction, have been substituted for the round pans. Taylor's pan, which is very much used, is of this kind, and is the first that was constructed for the application of high pressure steam (Figs. 120 and 121). The steam-pipes form a

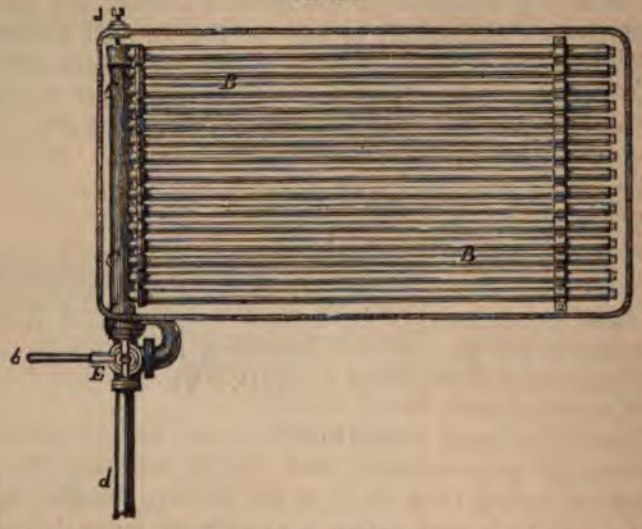
FIG. 120.



sort of grate *BB*, instead of being of a spiral form, the delivery and exit tubes being inserted the one in the other, so that each branch tube of the grate consists of two concentric tubes, one placed within the other. Steam of 3 atmospheres pressure enters by the inner pipe, and returns through the intermediate space between

the two. This is effected by dividing the principal pipe *C* (which

FIG. 121.



s kept in its place by the cock *E* and the screw *J*) longitudinally into two chambers. The steam passes through the pipe *d* and the cock *E* into that section of the pipe *C* that is nearest to the side of the pan where it is distributed to the inner pipes of the grate which are in connection with it. The steam returning through the space between the tubes, can only be delivered into the other compartment of the pipe *C* which is turned towards the middle of the pan, the outer tubes opening into this alone. From this compartment the returning steam escapes through the bent tube *F* and a descending pipe *Q*, to the boiler.

The cock *E*, which is moved by the handle *b*, is common to the admission and outlet pipe, and is divided consequently by a cross piece into two compartments, placed the one above the other; the upper compartment being in connection with the admission, the lower with the outlet pipe. The aperture in the centre of the bottom of the pan, with the cock *H*, is used for drawing off the evaporated juice. The cover of the pan *K* accelerates evaporation by creating a draught, the air entering at *l*, and issuing, laden with steam, at the opposite side, through the steam vent *N*.

The mode of conducting the steam is very ingenious in Taylor's pan, but the apparatus is complicated, and consequently costly and inconvenient in removal for the purpose of cleaning. The con-

centric arrangement of the steam pipes secures the perfectly equable distribution of the heat throughout their entire length; but the heating surface is much diminished. The pan, when in operation, is filled to $\frac{1}{3}$rd of its height, and this quantity of liquor is boiled in from 12 to 15 minutes.

Pecqueur's Pan.—Pecqueur's pan contains a system of simple tubes, which are all fed from a common steam pipe, and returns in a circular route through an outlet pipe, forming a continuation of the supply pipe to the boiler. The course of the steam is shorter in this arrangement, so that it does not lose so much of its tension, and a more uniform heating effect is the result. The admission and outlet tube together form one axis, around which the system of heating pipes, or the pan likewise as a swinging pan, can be revolved. Thus the emptying and cleansing of the pan can be effected without taking out the pipes. The whole arrangement is much simpler than that of Taylor.

Crespel's.—Crespel endeavoured to secure an easy method of cleaning his very extensively used pan, by soldering the semi-cylindrical heating tubes firmly to the bottom; the plan is successful, but the heating surface is considerably diminished, as the under surface of the pipes can only diffuse its heat to the surrounding air on the outside, and not to the juice in the pan.

Martin and Champonnois' evaporating pans are constructed of a very peculiar shape. The steam pipes are wide, hollow, perpendicular pillars, surrounded with wire gauze, over which the saccharine liquid is distributed from a cistern above, in such a manner that it runs in a thin layer over a hot cylinder. The juice is sufficiently evaporated after having passed three times over the heated surface. Although simple, and easily cleaned, this apparatus is objectionable, as it exposes the sugar to injurious contact with the air.

Boiling pans with uninterrupted action. — All the apparatus yet described belongs to the class in which only a certain quantity of sugar can be worked and finished at once. After being cleaned, it is used for a second charge, and so on. The method of working with this machinery is consequently periodical or interrupted. The capacity of the pan must under these circumstances be adapted to that of the clarifying vessels, in order that the juice, which is liable to spoil, may be worked up as it is clarified. The evaporating pans, corresponding with each clarifying vessel, must therefore together contain, when filled to a

certain height, the exact quantity of juice obtained from one clarification; and in like manner, the capacity of the boiling pans must accommodate the volume of juice from each corresponding evaporation. It has been shown, that in boiling sugar, the practice of adding juice in proportion to the progress of evaporation, cannot take place, as was the case in the manufacture of salt. For in this case, the sugar first introduced into the pan would be forced to remain three or four times as long as that which was added afterwards, and would suffer in proportion from the length of time that it had been exposed to the high temperature.

An apparatus that is constant in its action will produce much more in the same time, and under the same circumstances, than one that works periodically. For this reason, attempts have been made, with much trouble, to introduce uninterruptedly working evaporating apparatus into sugar-houses, which, on account of its more speedy mode of action, does not require to be so capacious. In this apparatus, fresh juice is constantly supplied from the one side, while evaporated juice flows off from the other. When the above-mentioned difficulty is to be avoided, and no single portions of the juice exposed longer to the heat than is necessary, every portion of the evaporated juice must be completely displaced by the fresh additions, without leaving a single particle adhering to the surface. It is almost impossible to carry out this condition to the full extent, and the uninterrupted apparatus has consequently not met with much favour, and in every case the deposition of precipitates would render a cleaning process necessary from time to time. As an illustration of this method of evaporating, Cody's apparatus may be mentioned. Imagine a pan 11 feet long by 2 feet wide, with seven flat semi-cylindrical steam pipes, such as Crespel's, the spaces between which form long channels for the circulation of the juice, which is heated in a warmer, before admission, by the waste steam. From the heater, the steam passes through a distributing pipe, along six of these channels, the whole length of the apparatus, and is brought altogether again in the seventh channel, through which it returns again, and is drawn off.

Brame-Chevallier's.—The concentration is effected in a very different manner in the apparatus of Brame-Chevallier (1834); which is constructed upon the principle of applying hot air. Two blast cylinders propel a current of air through a wide pillar with steam pipes. The current of air enters the pan with a temperature of 45° to 75° C. (113° to 167° F.); the pan is heated by a

special coil of steam pipes, and is furnished with a double bottom. The upper bottom is pierced in the manner of a sieve, and distributes the air admitted between the two in innumerable small bubbles through the juice, whence it is evolved, laden with moisture.

Evaporation by means of air is only advantageous, when it is desirable to keep the evaporating temperature below that of the ordinary boiling-point, as is certainly the case with sugar: time is thus economised. The cost of motive power rises, however, in proportion to the low degree of temperature that has to be maintained.

On the whole, the apparatus in question involves the expense of a motive power, in addition to the cost of the preceding arrangement, and is opposed in principle to all well-established experience, which proves the contact with air to be highly injurious.

Vacuum-pans.

Principle.—The well-established fact that sugar is less injured the lower the temperature at which its solution is evaporated, has given rise to the invention of a mode of evaporation under a less pressure than that of the atmosphere, for which we have to thank Howard. Howard's pans consist of close vessels, with that portion of their interior that is not occupied by the juice filled with rarefied air, which condition is kept up during the whole of the operations. Imagine the whole of the air to have been removed at the commencement, the space on boiling would rapidly become filled with steam, and an amount of pressure equal to that of the atmosphere would again be established. The vapour must consequently be absorbed as fast as it is generated. The apparatus being entirely closed, and furnished with a condensing apparatus for the steam, it acquires the appearance of a distillatory apparatus. The appellation, *vacuum-pans*, is obviously inappropriate, an absolute removal of pressure from the surface of the liquid, or a real vacuum, being never established.

The same quantity of water having to be evaporated as in the open pans, and the vapour, whatever its temperature, requiring the same amount of heat to produce it, no actual saving of fuel is effected by boiling under diminished pressure. The different vacuum-pans that have been brought into general use vary with reference to the methods by which the vacuum is produced, the

modes of sustaining it, and the manner in which the vapour from the saccharine juice is condensed and applied. It need hardly be stated that all vacuum-pans are heated by steam, and this requires to be of much lower tension than when applied to an open pan.

The boiling-point of the saccharine liquid depends upon its state of concentration, and upon the pressure exerted upon its surface after the rarefication of the air. The boiling is indeed that temperature at which the tension of the vapour becomes equal to that of the pressure exerted. At a pressure of 30^{mm} (1.181 inches), the boiling-point of water is at 30^0 C. (86^0 F.); at 11^{mm} (0.424 inches), 11^0 C. (52^0 F.); at 5^{mm} (0.191 inches), 0^0 C. (32^0 F.), &c. With saccharine solutions of ordinary density, at pressures indicated below in inches of mercury:

0.74—0.86—1.01—1.17—1.36—1.57—1.80

the boiling temperature in degrees C. is:

	46.1^0—	48.9^0—	51.7^0—	54.4^0—	57.2^0—	60.0^0—	62.8^0
Degrees F.	115^0—	120^0—	125^0—	130^0—	135^0—	140^0—	145^0

Pressure in in. mercury:	2.05 —	2.36 —	2.72 —	3.10 —	3.52 —	4.00
Boiling-point C: . .	65.5^0—	68.3^0—	71.1^0—	73.9^0—	67.7^0—	79.4^0
Degrees F.	150^0—	155^0—	160^0—	165^0—	170^0—	175^0

Howard's pan.—Howard's apparatus, patented in 1812, was provided with an air-pump for the production of the vacuum; and this was aided in retaining the vacuum by an arrangement for condensing the vapours. The vacuum is thus admirably kept up, and if everything is in good order, the pressure in the interior is brought down to 1 inch of mercury; at a pressure of $\frac{1}{2}$ inch mercury, the boiling-point of the syrup is at 46^0 C. (115^0 F.); at 4 inches, $65\frac{1}{2}^0$ C. (150^0 F.); at $5\frac{1}{2}$ inches, 71^0 C. (160^0 F.); at which temperatures steam, at a tension of $1\frac{1}{2}$ to $1\frac{3}{4}$ atmospheres, is sufficient to heat the pan; but all this is attained at considerable sacrifice, as the air-pump renders the apparatus costly and difficult of construction. A motive power is also requisite, which can only be remunerative in very large establishments. A very large quantity of water is also requisite for heating, condensing, and working the steam-engine; so that a sugar-house evaporating daily 300 hectoliters (=6,600 gallons) of juice of 4.5^0 B., requires the enormous amount of 500 hectoliters (=110,000 gallons) of water.

Roth's pan.—The same objections may be raised, although not to the same extent, against Roth's apparatus (1830). The evaporating pan is furnished with a double bottom and a coil of heating pipes in addition. The vacuum is produced from the commencement by a current of steam, with which the air is expelled from the apparatus; and it is maintained by the vapour rising from the juice being conducted into a special condenser, through which an incessant current of water is precipitated in the form of rain. The juice boils at a temperature of 75° to 80° C. (167° to 176° F.) The operation proceeds so rapidly, that the ordinary charge, which corresponds to thirty sugar-loaves, is boiled in from fourteen to sixteen minutes; so that 24,000 lbs. of sugar can be boiled daily in one of Roth's pans of 80 inches diameter; the consumption of water, however, amounts to five measures for every measure of juice. To avoid the necessity of an air-pump, and at the same time diminish the necessary quantity of water, Bayvet has introduced an improvement in Roth's apparatus, which renders it possible to employ the same water repeatedly for the purposes of condensation. The water, once used and rendered warm, is raised into a special vessel, and allowed to trickle down a series of woven bags, where it is cooled to the temperature of the air by the rapid evaporation from the surfaces of the bags.

The principle of Roth's apparatus—a current of steam and condensation in place of an air-pump—has since undergone numerous modifications. The most remarkable of these is:

*Degrand's apparatus,** with the improvements of *Derosne.*

Fig. 122 will illustrate generally the principles of the vacuum-pans. The apparatus consists of a steam-boiler, a vacuum-pan *C*, which is placed over an open pan *B*, that can be heated by a coil of steam pipes *b b*; the serpentine pipes *D*, which form the condenser, and are cooled by water flowing from the cistern *G*, and lastly of the cylinder *E*, for collecting the condensed water, and preserving the vacuum during the time that *C* is emptied and charged (*cylindre de continuité*). The vapour from the boiler passes through the pipe *a* into the heating coil *b b* of the pan *B*, and returns from thence to the boiler. The vapour produced by boiling the syrup in *B* passes through a tube (not shown in the figure) into the heating coil of the vacuum-pan *C*. The vapour generated

* In December, 1835, the Société d'Encouragement accorded the inventor of this apparatus a prize of four thousand francs, and declared it the best vacuum apparatus. The brothers Reybaud obtained a patent for it in the year 1834.

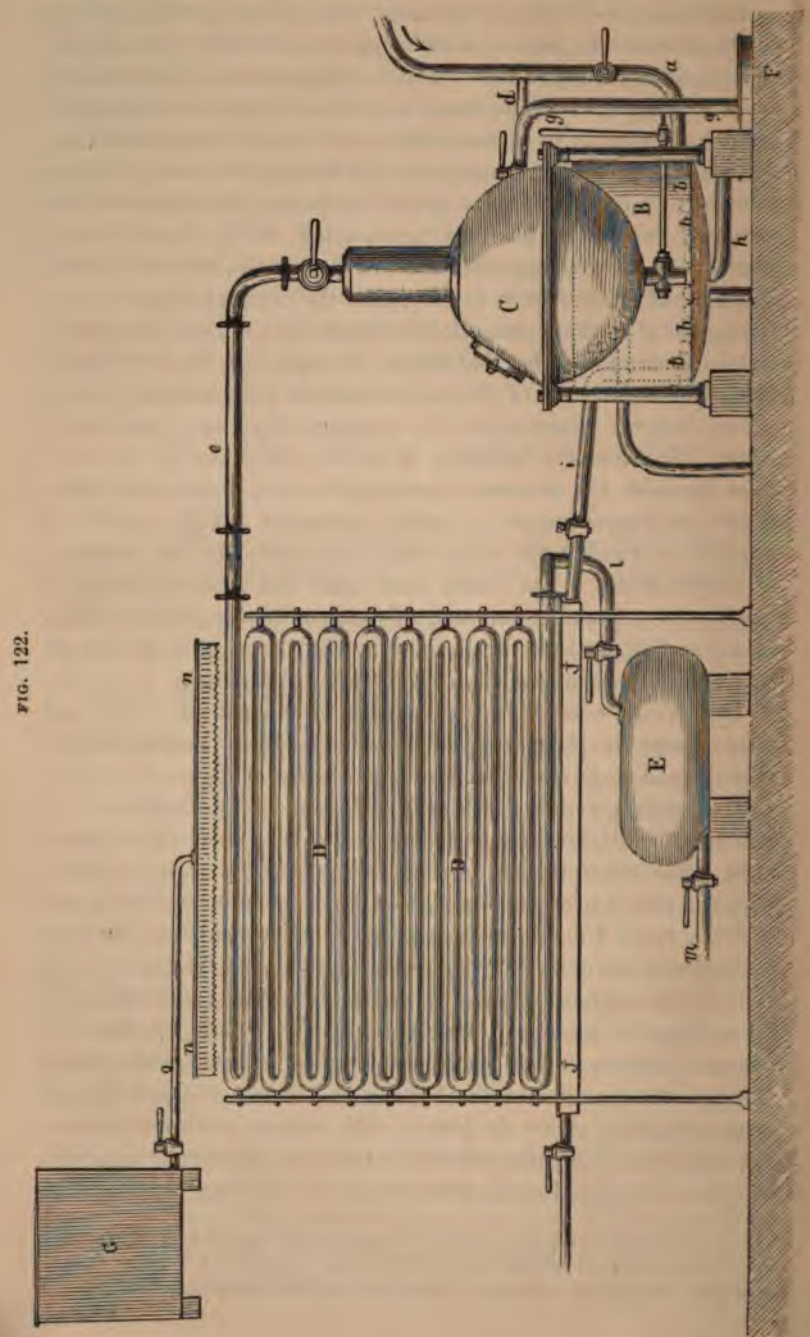


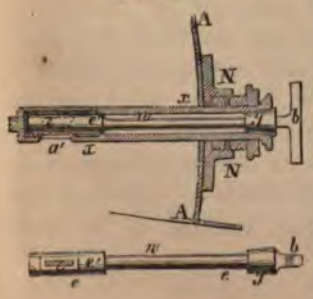
FIG. 122.

from the boiling juice in the vacuum-pan *C* passes through *e* into the serpentine pipe *D D* of the cooling apparatus. Above this a cistern is placed, containing unboiled juice, which is allowed to flow out by the pipe *o* into the funnels *n n*. These are, in fact, channels of the form of a V in section, with a notched edge and apertures at the sides; they distribute the juice in a number of thin streams over the serpentine tube *D*, which is thus constantly covered by a thin layer of juice, by the evaporation of which the vapours in the interior are condensed, and flowing through *l*, are collected in the cylinder *E*. The water of condensation can be easily removed from thence without injury to the vacuum, as *E* can be separated from it by a cock.

Such is the course through which the steam is conducted. The juice is put through the following series of operations. It arrives as fresh juice in the cistern *G*, in order to feed *D D*. From the serpentine coils of *D* the warm and somewhat concentrated juice flows into the receiver *j j*. The pan *B* is fed from this, in which the second concentration takes place. *B* is emptied by the tube *h* into the receiver *F*; whence again, by the tube *h*, the pan *C* is fed, in which the boiling is finished. The juice is raised from *F* into the vacuum-pan *C* by means of atmospheric pressure. If the vapour in *C* should not be sufficient, steam may be admitted at once from the boiler by means of the branch-pipe *d*.

When sugar is carried over with the vapours during ebullition, or when the boiling syrup overflows, this sugar is found in the condensed water of the cylinder *E*. The capacity of this is comparatively large, and intentionally so, in order that, in case any air should penetrate into the cooling apparatus, it may exert a less prejudicial influence. The cylinder *E* can be rendered a vacuum independently, by means of steam, without interrupting the progress of the operations.

FIG. 123.



Degrand's apparatus, as indeed all vacuum-pans, are furnished with contrivances for ascertaining at any moment the temperature of the boiling juice, the pressure in the pans, and for taking samples of the syrup. In order not to complicate the drawing, these have been omitted in Fig. 122. The former are ordinary thermometers and manometers. Fig. 123 represents the very ingenious and

peculiar contrivance for taking samples or small quantities of syrup at any time from the boiling pan, without injury to the vacuum. *A* is a portion of the lid of the pan with the tubulature *N*, to which a tube or barrel *x* is fastened, with such an inclination that the aperture *a'* at the end dips below the level of the syrup. Into this barrel a piston *e'* is fitted with a gimlet handle *b*, which can be moved backwards and forwards in the barrel in an air-tight manner. At one end of the piston rod *w* a conical piece *y* is fitted, while at the other the well-ground piston *e'*, with a cavity *z* corresponding to the aperture *a'*. If the piston be turned, so that *z* and *a'* correspond, *z* becomes filled with syrup; and if the handle be now turned one-half a revolution, *z* will take an exactly opposite position, and the syrup contained in it will be isolated between the piston and barrel. The piston may now be drawn out of the barrel sufficiently to admit of a sample of syrup being taken from *z*, without admitting air to the vacuum, for the outer end of the air-tight piston retains the barrel perfectly closed.

By means of a cock of precisely similar construction, a little butter may be introduced at any time into the pan, in order to moderate the turbulent ebullition.

It will be seen that the essential part of Degrand's apparatus consists in the condensation of the vapour produced in the vacuum-pan by means of the cooling action of the cold juice on the condenser, instead of by the injection of cold water. By this means the entire quantity of cold water, and a considerable amount of fuel, are economised, inasmuch as the juice dripping from the pipes of the condenser is heated up to a considerable temperature.

The plan is practically successful so far as the economy of water is concerned, but very objectionable in other respects.

The quantity of juice applicable to cooling purposes, in the ordinary course of the process, is insufficient completely to condense the vapour generated at the same time from the juice in the pan. The vacuum is consequently imperfect, and the boiling-point not so low as it should be. The apparatus consequently effects a saving at the expense of its main object; and the very important rule of preventing the air from access to the juice is altogether neglected in it, for in cooling, the juice is distributed over a very large surface of pipe. Condensation, by means of water and the air-pump, have consequently been again resorted to, to avoid which so much pains had been taken.

Pelletan's.—A principle, hitherto unapplied, of producing a vacuum in a direct manner by the condensation of steam, was proposed by Pelletan in the year 1830, and applied to his sugar apparatus in 1834. When an elastic body—for instance, a watch-spring—is brought from a state of rest into a state of tension, and suddenly released, it does not, as is well known, return to the original position, but passes considerably beyond it in an opposite direction. If a cubic foot of air is compressed into one-half its original bulk, and suddenly released from the pressure, it expands far beyond its original volume—for instance, to 2 cubic feet—before assuming its former dimensions. In the same manner, high-pressure steam, when first liberated, expands into a much greater bulk than that which it ordinarily occupies under the atmospheric pressure; it is rarefied in the first moment, as compared with the surrounding air. If high-pressure steam is admitted into a closed vessel instead of into the open air, the space in the interior of the vessel will be rarefied as compared with the outer atmosphere. This, in fact, is Pelletan's vacuum. The vapour issues from the conical mouth of a pipe into a globe of appropriate dimensions; the air expelled by the vapour escapes by an aperture on the opposite side of the globe. If the two apertures are now closed, the globe remains filled with expanded steam, and becomes a vacuum, and can then be brought into connection with the condenser and pan, which it consequently exhausts. The higher the tension of the steam before its exit, the more complete is its action. Experience has shown that the tension of the vapour ought not to be less than that of 4 atmospheres (60 lbs. on the square inch). The pressure in the interior is thus diminished to the extent of 50 centimeters (20 inches of mercury). Less steam is required in this than in the apparatus before described, but its tension must be greater, and this is always an objection.

The maintenance of the vacuum is preserved by a shower of water, as in Roth's apparatus; the boiling pan is likewise heated in the same manner with steam pipes, but in a much more convenient form. The pan is cylindrical, in the shape of a steam-boiler; the heating pipes are connected into a kind of grate, in such a manner that the whole system is attached to one plate, which closes the entrance to the pan. In order to clean the pan, therefore, it is only necessary to remove this plate with the grating of pipes.

Trappe's apparatus.—Trappe's apparatus is constructed with

the ordinary boiler arrangements and a condenser, by means of a shower of water. It is characterized, however, by the condenser terminating in a Torricellian tube of 32 feet in perpendicular height; the boiling is therefore conducted in the same vacuum as is always present above the column of mercury in the barometer; the arrangement, however, is of little practical value.

The new apparatus of Messrs. Pontifex and Co., described before under cane-sugar, is equally applicable to the concentration of juice from the beet.

Effective value.—The effective values of the different kinds of vacuum pans described above, as well as that of *Brame-Chevallier*, are collected in the following review, taken from the *Recueil Industriel.*

As a better means of comparison, the consumption is calculated for each apparatus at 300 hectoliters (=6,600 gallons), at 4.5° B. (sp. gr. 1.035 about) of clarified juice daily; or, in the working season of 140 days, at 10 millions of lbs. of beet, *not macerated.* In the opposite case, the consumption of cold water and fuel would be increased 21 per cent, and the cost of machinery from 15 to 18 per cent.

Apparatus of	Mean temperature of the heating steam.	Mean temperature of the boiling syrup.	Consumption of cold water in 24 hours with the apparatus.	Consumption of coal in 24 hours with the apparatus.
Howard . .	—	70°C. (158°F.)	5264 hectlit. = 115,608 gallons	6800 kilogr. = 6 tons 13½ cwts.
Roth . .	115° C. (271° F.)	81° to 90° C. (178°—194°F.)	4800 hectlit. = 104,600 gallons	6624 kilogr. = 6 tons 10½ cwts.
Pelletan . .	—	—	4600 hectlit. = 101,200 gallons	—
Trappe . .	—	—	4600 hectlit. = 101,200 gallons	—
Degrand .	110° to 112.5° C. (262°—270° F.)	75° to 87° C (160°—189°F.)	none	3300 kilogr. = 3 tons 4¾ cwts.
Brame . .	140° C. (316° F.)	93° C. (199.5° F.)	evaporated by air . . .	9724 kilogr. = 8 tons 11 cwts.

The rapid ebullition in the vacuum-pans causes no inconsiderable loss of sugar, which is carried over with the vapour; and this is not the case in the open pans. As much as 3 and 4 per cent of sugar have been detected in the water of condensation.

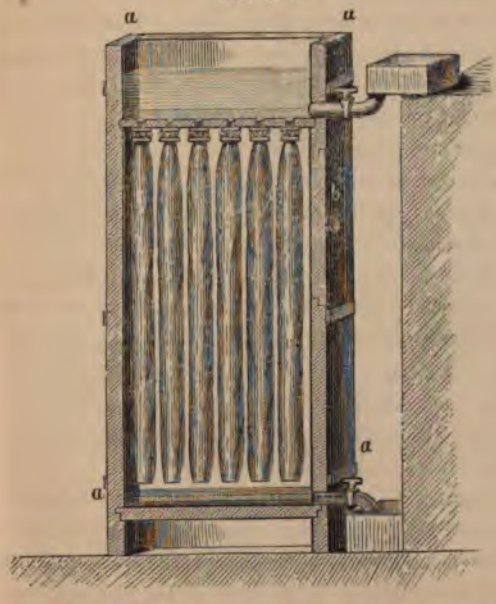
The Filters.

Until the commencement of this century, the filters were simple sieves, constructed of willow-baskets, lined with woollen cloth

(Howard's filter), and exerting no decolorizing action upon the syrup.

Historical.—The power of wood charcoal in decolorizing substances, first discovered by Lowitz, at the end of the last century, was first applied by Kels, in 1798, to decolorize syrup. The same substance was employed by Schaub, in Cassel, 1800, and by Guillon, in 1805; and lastly, the invaluable discovery of the far more energetic action of animal charcoal was made by Figuier, in 1811, and did not long remain unapplied. Derosne immediately proposed its use for decolorizing sugar, and the experiments of Payen and Pluvinet soon caused it to be generally adopted. The operations at first consisted in adding finely pulverized charcoal to the clarifying pans, the syrup being afterwards separated by a filter. Payen's filter was of this description, as also the well-known one of Taylor, Fig. 124.

FIG. 124.



Taylor's Filter.—The box *a*, *a*, 2 feet wide by 2½ feet deep, and 6½ feet high, is separated, at about 1 foot from the rim, by a false bottom, into two compartments. In the upper compartment, which is lined with sheet copper, the syrup for filtration is placed; in the lower, the apparatus for filtration. The filters are woollen bags, as many as twelve, twenty, or twenty-five in number, which are enclosed in other narrower linen bags, so as to cause them to fall in as many creases as possible. The bags are tied up below, and fastened at the upper end over brass mouth-pieces, which are tightly fixed into the false bottom.

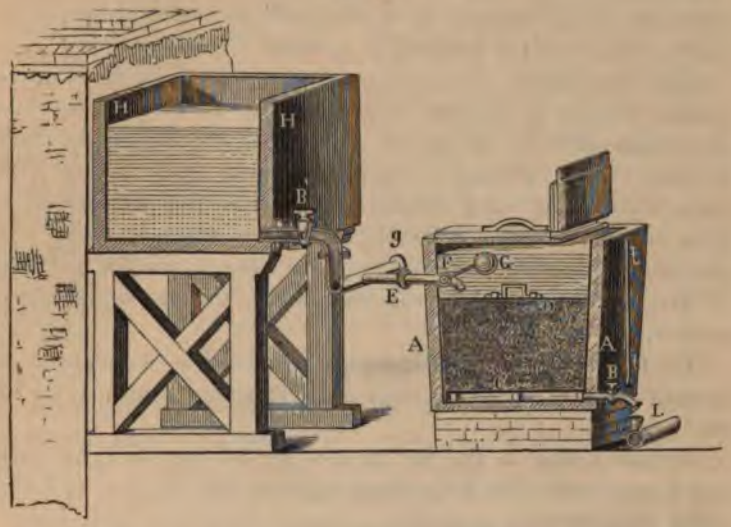
The fluid is thus forced through the filters by the hydrostatic pressure of the columns in the bags. The filtration is tedious and difficult, as the pores become easily stopped, and the filters require changing every one or two days, and often even thrice a-day (through the door *b*) ; and the first portions of juice require to be poured back, as they always carry off portions of charcoal powder. Taylor's filters are only of great practical value in those cases where the liquid has to be separated from a smaller quantity of not very minutely divided, but completely separated, precipitate, in fact, where straining is more requisite than actual filtration.

Before Taylor's time, in the year 1822, some not unimportant experiments were instituted by Pajot des Charmes, in which the principle of ranging the animal charcoal in layers in the filter, instead of adding it to the juice in the pan, was introduced, *i. e.*, the decolorization of the juice during the process of filtration. These, as well as the almost simultaneous experiments of Dumont and Dubois (1823), were unproductive until Dumont, in the year 1828, brought forward the filtering apparatus that bears his name, producing an epoch in the manufacture of sugar, and rendering animal charcoal, for the first time, really available. An apparently unimportant observation led to this result.

Up to this time, finely pulverized charcoal alone was employed, which so impeded the passage of the thickly fluid syrup, whether the charcoal was introduced into the pan or not, that only very thin layers could be brought into the filters, and consequently as much charcoal as was necessary could never be employed, even if the price of the material would have admitted of its application. This was rudimentally changed when it occurred to Dumont to granulate the charcoal, *i. e.*, to employ charcoal of the grain of coarse gunpowder in the filters, from which all the dust and fine powder had been previously removed.

Dumont's Filter.—Dumont's filter consists essentially of a box *A* (Fig. 125), which is lined internally with thin sheet copper, and furnished with brass flow-off pipe and cock *B*, situated immediately above the bottom. *C* is a moveable perforated copper bottom, placed upon supports. Above this perforated bottom, a moistened, not very thick, piece of cloth is placed, care being taken that it fits tightly to the sides; the granulated charcoal is then introduced, which has been thoroughly moistened previously, without having the appearance of being wet. The introduction of the charcoal requires care and attention; it must be arranged in layers, and

FIG. 125.



each layer must be pressed down and spread out before the subsequent one is placed upon it. The entire stratum of charcoal is generally about 14 inches in thickness; it is covered by a second cloth, and the second perforated bottom *D*, which is constructed in precisely the same manner as *C*. Between *D* and the lid *K*, a branch *E* of the main pipe *g* enters, which main pipe supplies all the filters from the reservoir *H*, through *B'*. The float *G* regulates the position of the cock *F*, in such a manner that the syrup is always preserved at the same level above *D*. The air expelled by the syrup in trickling through the charcoal, and from the space between the bottom and *C*, escapes through the pipe *t*. The decolorized syrup is carried forward by *L*. When the power of the filter is exhausted, and the syrup appears thick or coloured, it is conducted by a gutter to a vessel set apart for its reception.

The granulation and removal of the dust from the charcoal allow interstices to remain sufficiently wide for the juice to pass quickly and easily through, and the filters are not so liable to be choked. The size and uniformity of the grain, on the other hand, are sufficient guarantees that the syrup cannot pass through without coming properly in contact with the charcoal, except by neglect. The mode in which the syrup penetrates layer by layer through the charcoal, brings all the decolorizing power of the

charcoal into play. Again the saccharine liquid meets with more active layers of charcoal, as it continues its course through the filters, and stands consequently a better chance of being thoroughly decolorized. One very great advantage which these filters possess consists in the ease with which they can be cleaned, while the spaces between the grains of charcoal are sufficiently small to prevent the successive layers of liquid from mixing with each other. The water employed for moistening the charcoal is thus almost entirely expelled by the first portions of syrup, and can thus be separated, and in the same manner, the last portions of syrup are displaced by the wash-water, without being mixed with it.

The size of the filters are generally calculated to contain between 1 and 3 cwts. of charcoal; their effective action continues for 12 or 15 hours.

Dumont's filter is the one in most general use, but it has been much improved. The large filters introduced by Hecker, at Strasburg, are extensively employed. They are from 10 to 20 feet high, $1\frac{1}{2}$ to 3 feet in diameter, and hold as much as 20 cwts. of charcoal, which is *"steamed"* before being used, *i. e.*, moistened and warmed by the introduction of steam, to such an extent that the syrup is not cooled when poured upon the charcoal. This previous application of heat, as well as the pressure occasioned by the syrup flowing from a 10 or 20 feet higher elevation, are decided advantages.

Charcoal filters of very much larger dimensions are used in the British refineries.

Weinrich's Filter.—Finely pulverized charcoal, on account of the greater surface it presents, has naturally a more powerful decolorizing action than that which is merely granulated. Weinrich has endeavoured to take advantage of this principle, by mixing finely-powdered charcoal with sand. The idea is not, however, original, but was previously tried by Pagot and Dumont. Filters of this description are not convenient, on account of the difficulty of again using the charcoal, and have never come into general use.

Peyron increases the pressure in his filter, which in other respects resembles that of Dumont, by giving it the form of Real's extract-press, the principle of which is also followed in Hecker's filter.

Peyron's Filter.—Peyron's filters are the only so-called *"permanent"* filters, or such as can be renewed after exhaustion, without

being entirely taken to pieces. The charcoal they contain is revivified and washed in the filters themselves, the former being affected solely by fermentation. (See Appendix on "Animal Charcoal.") It appears, however, that they have not been found successful. From 3 to 5 per cent of the weight of the beet is required in charcoal, or hardly half the amount of the sugar. Yet this small quantity would be fatal at the present price of animal charcoal, and the advantages of Dumont's filter would prove illusory if the charcoal could not be renovated, and employed several times in succession. Dumont's filters only came into general use after the amount of fresh charcoal was reduced on the whole consumption, by the process of renovating, to about $\frac{1}{17}$ part.

After the operation of clarifying or defecation (pages 369 to 383), the juice is submitted to

f.) The first filtration and evaporation.

Filtration.—The juice, while still hot from the defecating vessels, is allowed to flow directly upon one of Dumont's filters, filled with renovated charcoal. The water that is first expelled is rejected; then a weak saccharine solution is obtained, which is collected by itself; and lastly, the syrup. The high temperature of the filters favours filtration, the syrup being more limpid, and the decolorizing power of the charcoal increased. The effect produced by this filtration is a perfectly clear solution, the separation of a portion of the lime, and the removal of colour by the absorption of organic matters. The following table, by Schatten, exhibits some important data with reference to the last effect produced:

Before treatment with animal charcoal, 100 parts of juice yielded.		After treatment with animal charcoal, 100 parts of juice yielded.		Nature of the soil on which the beet had been cultivated.
Lime.	Precipitate with basic acetate of lead.	Lime.	Precipitate with basic acetate of lead.	
0.179	0.514	0.047	0.426	In the third year after manuring.
0.169	1.120	0.056	0.916	Freshly manured.
0.147	0.686	0.042	0.502	In the third year after manuring.
0.170	1.426	?.	?.	Soil containing nitre.

The organic matters precipitated by acetate of lead were consequently, in the first case, only 0.088, in the second, 0.204, in the

third, 0.184. The lime, separated on the other hand, was in the first 0.132, in the second, 0.113, in the third, 0.105.

A gelatinous substance is sometimes deposited in the lowest part of Dumont's filter, and on the cocks attached to it, which was often erroneously supposed to be derived from the undecomposed gelatin of the animal charcoal. Braconnot had an opportunity of investigating this substance. He describes it as nearly colourless, semi-transparent, tasteless and inodorous, and difficultly reducible to powder. It swells up in water to a translucent jelly, which binds imperfectly, and bears a resemblance to paste, or pectic acid; but it neither becomes blue with iodine, nor exhibits any acid reaction. It leaves a small quantity of ash upon incineration, is soluble in muriatic and nitric acids, as also in the alkalies, but not in lime-water. It is precipitated from solution in hydrochloric acid by alkalies, but not from a nitric acid solution, which acid does not convert it into mucic acid. It is impossible to determine, from the vague and imperfect statements of Braconnot, whether the substance in question, which he supposes to be gelatin, is really a new species of vegetable gelatin (Bassorin), or whether it is related to the gelatinous acids, and why, in the latter case, it has escaped precipitation during clarification.

Evaporation.—The syrup that has passed through is now evaporated, for which purpose open pans are always employed, sometimes directly over the fire, at others heated by steam upon Halett's, Crespel's, or Taylor's plan. Whichever pan is used, it must be well cleaned and polished before use. A little water is first heated in the pan to warm it; this is then removed, and the pan is filled with syrup, to a depth of about 8 inches, that the boiling-point may not be unnecessarily raised. The evaporation proceeds very rapidly; much froth is produced, which has a great tendency to flow over. The workman constantly keeps the steam cock in hand, so as to check the boiling at any moment. It is, however, often necessary to add a little butter to check the excessive frothing. During evaporation, a considerable quantity of ammonia is evolved, which is easily perceived by its odour.

The object of this evaporation is the separation of the foreign matters still dissolved in the juice. Concentration itself effects this with many of them; a portion of the lime is precipitated by the absorption of carbonic acid. The chief cause, however, is attributable to the action of the lime upon the organic nitrogenous matters, which gives rise to the evolution of ammonia;

these form products of decomposition, some of which are precipitated with the lime upon evaporation. It has already been stated, that this reaction of the lime is entirely dependent upon temperature, which should exceed 100° C. (212° F.) If the vacuum pan is employed for this evaporation, as is practised by some manufacturers, a very inferior syrup to that obtained from the open pans is produced, by means of a costly apparatus, and there are good reasons for preferring the latter. Hochstetter examined the deposits which are formed by precipitation in the manufactories, and found them to consist of:

Leucin (a crystalline substance, always produced by the action of alkalies upon albuminous bodies); two *lime-salts*, with organic acids, the one separated by acetic, the other by hydrochloric acid; a *black substance resembling humus*, which swells up when heated, melts, and evolves an odour of burnt horn; a *lime soap*, produced by the fat added during evaporation.

Besides these products, soluble lime-salts have been produced, and in the evaporated juice a number of foreign organic matters are found, changed more or less by the action of heat and alkali.

It has been proved above that the sugar is not acted on before the formation of these substances, *i. e.* it takes no part in the decomposition of the organic matters during evaporation, as long as free lime or alkali are present. Hence the rule for maintaining the juice alkaline during evaporation, and rather to add some milk of lime before clarification than that there should be any deficiency. This is advantageous in more respects than one. The nitrogenous substances in the clarified juice are themselves very little absorbed by the animal charcoal; but when changed in the manner stated above, they are readily absorbed. During evaporation, therefore, a portion of the foreign matters are separated, and another portion is transformed in a manner to render it separable. The evaporation should be continued as long as the evolution of ammoniacal vapours is perceptible, but must not be continued long enough to increase the consistence of the syrup to such an extent as to render its passage through the filters difficult. The limit lies between 20° B. (=sp. gr. 1.16, Magdeburg), and 33° B. (=sp. gr. 1.295, France). Now follows:

g.) The second filtration and the boiling process.

The liquor.—The second filtration is likewise carried on in one of Dumont's filters, but charged with fresh animal charcoal,

although in other respects in a precisely similar manner to the first. The precipitate formed during evaporation is here separated, together with some organic matters absorbed by the charcoal; the syrup becomes colourless, and the free lime is absorbed. When the operations are properly conducted, and the material is good, this absorption must be so complete that no precipitate is produced in the filtered syrup or liquor by carbonic acid. The liquor only contains organic matter and the different salts. An experiment of Schatten, proved that the smaller portion only, and indeed only a very small quantity of organic matter, probably only the nitrogenous and colouring matters, but not the mucus or gum, &c., are separated by the second filtration. Juice from the beet, grown upon so-called saltpetre soil, yielded, after clarification, 1.426 per cent of precipitate, with basic acetate of lead; the liquor obtained from the same, diluted to a like consistence, yielded 1.212 per cent of precipitate of a similar character; so that, by evaporation and the second process of filtration, only 0.214 per cent had been removed. The liquor is not submitted to any further purification, but at once put under the *boiling* process, in order to yield solid sugar.

Boiling the liquor.—The last evaporation is called boiling, the object of which is to remove as much water, or to bring the juice to such a state of concentration, as is necessary to the deposition of crystals of sugar. The very considerable specific gravity of the fresh liquor, and the high boiling-point which it consequently possesses under ordinary circumstances—it begins at 104° C. (220.5 F.), and finishes boiling at 130° C. (266° F.)—expose the sugar to great danger of decomposition during boiling under the continued influence of heat, and vacuum pans have been almost universally employed; those furnished with an air-pump and condenser being preferred.

The stormy and tumultuous boiling, as it occurs in the vacuum pan, causes a small quantity of sugar, when the bubbles burst, to be carried away with the current of vapour; this sugar is found in the water of condensation. In many factories which work with a vacuum, besides the loss thus sustained, a serious evil is also connected with it. In such cases—namely, where there is a deficiency of water—an attempt is made to use the condensed water by passing it through a series of stone-ware pipes, which circulate through the building, backwards and forwards, in a ditch, and discharge into a reservoir, whence the water is raised to the condensers,

and used in the form of rain for the condensation of the vapour. When this water has served several operations, it acquires the property of undergoing fermentation, with the evolution of nauseous odours and the production of acids, which attack the metal-work connected with the pumps and apparatus. This action is facilitated rather than diminished by the ammonia, which is usually present in this water.

Taking a proof.—The boiling process is finished as soon as a sample exhibits the proper degree of concentration, which is usually attained in the short space of a few minutes. The test does not consist in ascertaining the amount of sugar or the specific gravity by scientific means, such as hydrometers, saccharometers, &c., but, on the contrary, is thoroughly empyrical, although very trustworthy, the processes, known abroad as the *string-* the *bubble-* and the *water-test,* having gradually grown out of practical experience.

The *string-test* consists in taking a portion of sugar between the finger and thumb, rubbing the latter together, and then drawing out the sugar between them. The form and length of the thread thus obtained are the criterion by which the state of concentration is estimated. The thread must attain a certain length without fracture, and the separated parts must shrink together uniformly.

For the *bubble-test,* a skimming spoon or colander is dipped into the liquor, the excess of liquor is allowed to run off, and the surface is then blown upon with some degree of force. When the juice possesses a proper consistence, the air, in being forcibly propelled through the holes, produces bubbles which separate in the form of small air-balloons. In the *water-test,* the consistence of a drop of liquor is judged of when allowed to fall and cool in cold water. It should flatten by its own weight, and not adhere to the fingers.

A distinct, well-defined bubble-test corresponds to about 86 per cent of sugar, and a boiling-point of 120° C. (248° F.); a moderate thread corresponds to 78 per cent sugar and 108° C. (226° F.)

Burning.—When the boiling is executed in shovel-pans (teaches) over the open fire, the liquor is very subject to burn. According to an observation of Schatten, the tendency of the liquor to burn is connected with the amount of lime it contains, which at that stage

of the process is in the form of a lime-salt. The examination of a series of different liquors, from 1.200 to 1.225 sp. gr., and their behaviour on boiling, proved that the amount of lime ought not to exceed 0.076 per cent, when the operation is to be properly performed.

A similar cause will probably account for the somewhat enigmatical phenomenon known in German sugar-houses by the term *Fettkochen*. This occurs with strongly alkaline liquor, which should never be produced under proper management, and is manifested at a certain stage of concentration, when evaporation and tumultuous ebullition suddenly cease, and the liquor is quite at rest in the pan. An increase of heat does not improve this state, but, on the contrary, deteriorates the liquor by converting the sugar into caramel. Sulphuric acid, added in sufficient quantity to neutralise the alkaline reaction, is said to be the best remedy for this state of the liquid.

Cooling, filling, and claying.—The operations of *cooling, filling,* and *claying* the boiled liquor, are in all essential points the same as those practised in the refining processes. The greater impurity of the juice, however, the consequent impurity of the syrup and the large amount of saline matter present, give it a much more disagreeable flavour than the corresponding product from the sugar-cane. These foreign matters render good purification doubly necessary, on account of the taste, and interfere with the formation of the crystal. For these reasons, the larger or bastard-moulds are preferred to the smaller. The temperature at which the boiled liquor should be filled into the moulds from the coolers is dependent upon the nature of the liquor itself, and upon the successful performance of the boiling process; it varies from 82° to 85° C. (180°—185° F.)

The liquor is left to drain in the moulds for twelve or fourteen days. The syrups are again evaporated, either immediately, or diluted again with water, passed through the charcoal filters, then boiled and crystallized a second time. The dilution with water, is only necessary with inferior liquor, and when the juice is difficult to manage. Under the present system of improved clarification, proper management in the addition of lime and good filters, a marketable product is obtained in the first instance; the syrups are collected in a reservoir, in which they remain for a considerable time, and afford, without further evapora-

tion, another pretty abundant crop of crystals, when they are considered sufficiently exhausted. Clay is little used at present in the process of claying, but almost universally liquor or water.

A mould, containing from 30 to 40 lbs. of sugar syrup, yields, after claying with liquor or a solution of sugar, at the expiration of ten or twelve days, or when clay is used, in twenty to thirty days, from 12 to 15 lbs. of lump sugar.

Schützenbach's method of claying.—Schützenbach has recently invented a method of claying, in which the claying with syrup is converted into a more systematic process of washing. This method is completely successful, and enables the manufacturer to obtain nearly the whole produce as first-quality sugar.

The liquors are boiled down until they contain only 22 to 24 per cent of water, in order that they may be less subject to change in the higher degrees of temperature, in the crystallizing rooms. They are introduced into crystallizing vessels of 8 to 10 hectoliters (176 to 220 gallons) capacity, that the grain of the crystals may be uniform—neither too fine nor too coarse. After the crystallization is completed, the mass is brought into so-called purifying boxes. These are wooden reservoirs, about 18 inches square, and 6 inches deep, the bottoms being composed of iron-wire gauze. The ordinary moulds of the same capacity are 26 to 32 inches high; the mass, therefore, forms a layer in the boxes, which is only $\frac{1}{4}$ or $\frac{1}{5}$ as deep, but presents a surface forty or fifty times as large as when in the moulds. The green syrup flows into a pan of tinned iron, placed below, and is accelerated in its passage by a current of steam passing through the space occupied by the boxes. The air is thus kept in a state of moisture, corresponding to 75° of De Luc's whalebone hygrometer, at the normal temperature of the room, 31° C. (88° F.), which prevents the syrup from drying on the crystals, and yet is not sufficient to dissolve them.

As soon as the green syrup is separated, the crystals remaining in the boxes are moistened with a better kind of syrup (clayed), and this operation is repeated with better syrup each successive time, until the sugar is sufficiently purified, which is generally accomplished after the fifth time, or after from eight to fourteen days. The waste syrup is employed to wash impurer crystals, as long as it is capable of effecting such purification, when it is itself boiled down again for sugar. The crystallization of the

syrups is however effected at higher temperatures, in order to obtain better and harder crystals.

Schützenbach asserts that by his process it is possible to obtain the whole amount of sugar in the beet, with the exception of 1 or even only of ½ per cent; only two products being obtained, refined sugar of first quality as pure and white as the finest cane-sugar, and molasses, only fit for the production of rum or spirits; an assertion which Dumas corroborated in every respect, before the Academy of Sciences in Paris. Although the accuracy of these assertions has still to be proved, it is nevertheless certain that Schützenbach's process is more rational and practicable than many of those previously described, affording more sugar, and that of better quality, with less loss and less labour.

Produce.—The entire produce of raw sugar from the beet, which did not formerly exceed 6 to 7 per cent, is now calculated at 7 to 8 per cent, or even a little higher. Of these, 3 to 4 per cent are of the best quality (Melis), 2 to 3 of second quality (Farin), and 1 to 2 per cent of syrup; all of which are commercial articles. At most, not more than 2 per cent of molasses are obtained.

Raw beetroot sugar is not adapted to the manufacture of sugar-candy, and not more than 20 per cent of it can be added to the syrup intended for the production of sugar-candy. It is said to yield crystals of a different form, being longer and flatter. The taste of the adherent syrup is probably still more prejudicial to its application.

Cube sugar.—Some time ago, small cubes of beetroot sugar, about half an inch square, were introduced into commerce, for which Grebner in Moravia took a patent. For the preparation of this cube-sugar, two metallic slabs are employed; the one is pierced with quadrangular holes at regular intervals, the other is furnished with projecting four-sided prisms, which fit exactly into the holes. The first plate is laid upon a board, which closes the holes at the bottom. Finely ground, moderately moist sugar is now spread out over the plate, by means of a sieve, so that the holes are filled with it; the excess is then scraped off, the second plate is applied, and pressed down with a lever, so that the sugar only half fills the holes forming the cubes, which are then pressed through, upon the removal of the board, to an iron plate and dried. They are sold in packets, containing 1 lb. each.

The sugar in this form, on account of the uniform size of the pieces, admits of much easier division into portions, which is convenient for domestic purposes and in hotels. But there was another motive, besides the convenience for retail consumption, in giving the sugar this form. The manufacturer is enabled by this means to get a higher price for inferior kinds of sugar, which could not otherwise be brought into a saleable form.

It does not appear that the plan has been generally successful, as it was probably too soon discovered, that starch-sugar was largely mixed up with the cubes.

Molasses.—The molasses contain the whole of the uncrystallizable sugar, the products of the decomposition of the sugar, and the other organic matters of the juice, besides the saline matter, gum or mucus, to all of which conjointly they owe their very nauseous taste, being far more disagreeable than the molasses of the refiner; besides this, they are saturated with raw crystallizable sugar. They may be used, mixed with the refuse from the press, as fodder for cattle, or better for the production of spirits, containing more than half their weight of solid sugar; they yield about 30 per cent of their weight of alcohol. A residue remains after this distillation, which, when dried and calcined, leaves 10 or 12 per cent of the weight of the molasses, in the form of a saline mass, very rich in alkali: it contains

Sulphate of potash . . .	7—11 per cent.
Carbonate of potash . . .	17—20 „
Chloride of potassium . .	27—45 „
Carbonate of soda . . .	25—34 „
Cyanide of potassium . . .	traces.

The production of potashes may consequently be very advantageously connected with the distillation of molasses, the latter being so diluted as to afford 4 to 5 per cent of alcohol; the residue is used for diluting fresh portions of molasses, and so on. The amount of saline matter is thus concentrated to the proper degree, and can be worked up at the close of the season, the quantity not being sufficient to furnish a continuous process. In manufactories consuming daily 600 cwts. of beet, about 5 or

6 cwts. of mineral ingredients are found, and therefore 3 to 4 cwts. of this saline mixture.*

When the calcined saline mass is purified by solution, a double salt crystallizes $= KaO, CO_2, + NaO, CO_2 + 12$ aq., which can be converted by carbonic acid into carbonate of potash and bicarbonate of soda.

Schützenbach's method of obtaining sugar from beet.

An essentially new method for the manufacture of sugar from beet, introduced about eleven or twelve years ago, and called, from the inventor, Schützenbach's method, created considerable sensation when first published, and threatened, for some time, to supersede the customary French process. Although this process has not been carried out to any great extent, and has even been found impracticable in several places where attempts were made to introduce it on a large scale, it merits the following short notice.

In the introduction to this chapter, it was stated that one of the chief sources of loss in crystallizable sugar, according to the usual mode of manufacture, consisted in the difficulty, or rather impossibility, of preserving the beet for some months *without change*. It was pointed out that the large amount of water contained in the bulbs, or the high state of dilution in which the organic matters were held in solution in the cells of the beet, the easy oxidizability of one portion of these, and, on the other hand, the insuperable tendency of the beet to germinate and grow, produced changes which rapidly extended to the crystallizable sugar. In accordance with well-established experience, the produce diminishes progressively with the duration of the season, *i. e.* the beet yields a lesser proportion of sugar the longer it is kept.

The fundamental idea, in Schützenbach's method, consists in obviating at one stroke these injurious transformations, previously to operating upon the beet, by drying the bulbs immediately after harvest. In this state, therefore, after the removal of the water

* In Waghäusel, for instance, *vide* p. 247, where 30 millions of kilos. = 600,000 cwts. of beet are annually worked, the quantity of this saline mixture amounts in the year to from 3 to 4,000 cwts.

and the destruction of the germinating power, the roots may be preserved for any length of time without change. While, under ordinary circumstances, the operations could only be carried on between October and March, and the capital lay unproductive from March to October; with a proportionate diminution of size in the apparatus, the works may now be kept in operation during the entire year, and a freer scope is given to the trade. It is also proved that drying, when properly executed, preserves the whole of the sugar in the crystallizable form. According to the experiments of Holger, the following loss is experienced between 29° and 34° C. (85.5°—94.5° F.) by:

Whole, pealed beet . . .	77.5 p.ct. water,	leaving	22.5 p. ct. dry substance	}	in 4—9 days.
„ „ . . .	80.7 „	„	19.3 „ „		
Beet, cut into cubes . . .	83.2 „	„	16.8 „ „		
„ cut into slices . . .	78.1 „	„	21.9 „ „		
Whole roots, unpealed, white	58.9 „	„	41.0 „ „	}	in 9—13 days.
„ „ yellow	61.8 „	„	38.1 „ „		
„ „ „	64.6 „	„	45.6 „ „		
„ „ red	54.4 „	„	35.4 „ „		

According to these experiments, the beetroot dries best when it is cut up into cubes.

According to the results obtained in the manufactory at Ettlingen, working Schützenbach's process, the cubical pieces of beet lost 84 per cent of water when dried upon a large scale, leaving 16 per cent of dry matter.

It is obvious that other advantageous conditions are connected with this process. Fresh beetroot can only be transported to short distances, on account of the weight of water it contains ($\frac{4}{5}$ths of its weight), if sugar is to be prepared from it with advantage. Dried bulbs, on the other hand, are only about $\frac{1}{6}$th as heavy as the fresh bulbs, with the same quantity of sugar; they can consequently be transported six times as far, and from a surface of ground thirty-six times as large, and the sugar manufacturer is benefited in this same proportion by the diminution in the cost of carriage.

Practical details.—In order to show the value of Schützenbach's process in a still more conspicuous manner, we add a short description of it.

The cubical slices of beet (really parallelopipeds), which are cut by a machine specially constructed for the purpose, are spread out 1 or 2 inches high, upon hurdles or slides of wire-grating, in

a drying chamber. A better arrangement is to connect the cutting machine with the drying-house by an endless network of wire, which traverses the latter over several pairs of rollers, in a horizontal direction. A special piece of machinery converts this network of wire into a system of moveable hurdles. The first pieces of this system take the cubical segments of beet from the cutting machine, and convey them into the drying chamber, where they form the uppermost layer. The continued motion of the machine causes them to fall to the second, then to the third layer, and so on, until, at the expiration of ten hours, they reach the last, and are perfectly dry.

A current of hot air passes through the hurdles or layers of wire-gauze, the temperature of which is not allowed to exceed 60° or 70° C. (140° to 158° F.), in order to avoid burning and fermentation; nor is it permitted to fall below 37° C. (99° F.) The hot air is either produced by the circulating flue of a fire, after the fashion of malting-kilns, or by a coil of steam-pipe.

The dry beet is ground at once to powder, and in that state is submitted to the subsequent operations. The first of these consists in extracting 16 parts of the flour with 36 parts of water, previously rendered acid with 2½ to 3 parts of sulphuric or sulphurous acid. This extracting process is carried out upon the maceration principle, in such a manner, therefore, that, the weak extract from the exhausted beet is employed after the first operation for extracting the fresh portions of flour. The neutralization of the sulphuric acid (used as a preventative to fermentation), or of the sulphurous acid (added as a deoxidizing agent), is followed by clarification with lime, and the usual operations.

Advantages of the process.—The albumen is rendered, for the greater part, insoluble by the process of drying, and remains with many other foreign matters in the beet refuse; a purer juice is thus obtained, requiring a smaller quantity of lime and of animal charcoal. The juice is also richer, for the whole of the sugar is contained in a solution having a specific gravity of 1.168 or 21° B. This method of manufacture has consequently all the advantages as well as the disadvantages of the process of maceration. In Ettlingen, the 16 lbs. of dry beet flour yield, on an average, 11 lbs. of syrup of the proper consistence, from which, on an average, after the syrup has separated, 7 to 8 lbs. of granulated raw sugar, and from 1½ to 2 lbs. of molasses, are obtained. At Waghäusel in Baden, where 30 millions of

kilos. of beet are annually operated upon for sugar, on Schützenbach's plan, the surface of the drying apparatus occupies 200 square feet. Each square foot dries, in twenty-four hours, 30 kilos. of beet (each lb. of coal evaporating 8 to 9 lbs., or, according to others, 6 lbs. of water), yielding 16 to 20 per cent of dry substance. They afford a juice, upon extraction, of 20^0 to 25^0 B. (sp. gr. 1.158 to 1.206), or containing 40—42 per cent of sugar; while freshly expressed juice has a density of only 7^0 to 8^0 B., and contains only 10 per cent of sugar. In the ordinary process, therefore, there are about 83 per cent of water to be evaporated; while, upon Schützenbach's plan, there are 83 + 36 per cent, or $\frac{3}{7}$ths more. There can be no doubt that, if the extracting was conducted in a more methodical manner, syrups of every degree of concentration might be obtained, and consequently such as would be at once crystallizable. This has been the object aimed at in the improvements introduced by Duquesne upon Schützenbach's method; but it will be obvious that fresh difficulties have then to be encountered in the clarification and decolorization, for syrups of such high specific gravity offer as great difficulties in the clarifying pan as in their passage through the charcoal filters.

The extraction of the beet pulp with water, which has been mixed with milk of lime, may be considered in itself a clarification of the beet; but is only completely successful when the circumstances and the character of the beet are suited to it. The temperature of extracting cannot be raised to the proper height for clarification, without giving rise to still greater obstacles. Independently of the difficulties of clarifying, we have those of decolorizing; and if this process is carried out *before* the syrup has become very dense, it again becomes coloured in the subsequent concentration; and if *after*, the syrup passes with too great difficulty through the charcoal.

Schützenbach's process, notwithstanding its many advantages, has been forced to give place to the older French method, in consequence of the greater consumption of one of the principal requisites, fuel, which it unquestionably involves; and likewise on account of completely failing in its ulterior object, that of widening the sphere of connection between the manufactory and the cultivation of the beet. The drying must be carried out rapidly and economically, if it is to afford security against any change in the sugar. Complicated and highly perfect apparatus is requisite for

this purpose, which presupposes much mechanical aid, as well as a considerable capital; and for this reason a sort of centralization, which renders the carriage of fresh beet almost indispensable.

The drying process of Schützenbach is only applicable in a large manufacturing establishment, on a grand scale, and generally in connection with the manufacture of the sugar itself. If a system of drying existed, which could be carried out on a small scale with the same certainty of success by the agriculturist, the manufacture of the sugar could then be separated from the culture of the beet, and the main question respecting the home production of sugar would be solved. The culture of beetroot would then only be prosecuted where the position, character of the soil, and other necessary conditions, were favourable. The manufactory would be established in a locality where fuel, labour, and means of transport were cheapest, and thus both branches of industry would benefit.

It is only under conditions such as these that Schützenbach's process is likely to play the important part in the sugar manufacture of which it appears capable.

Review of the production of Sugar, with reference to political economy.

In the course of this chapter, the present condition of the beetroot and colonial sugar manufactures have been noticed separately in their proper places. The chief obstacle to improvement in the manufacture of cane-sugar was found to lie in a bad arrangement of the division of labour, each, even the smallest grower of the cane, being also a manufacturer of sugar; instead of separating the production from the growing of the cane, centralizing it, and thus enabling better apparatus to be brought to bear upon it.

In the case of beetroot sugar, the great difficulty consisted in the want of a proper relation between the growing of the beet and the preparation of sugar from it in the factories. Lastly, it has been pointed out that the improvements have been directed too exclusively to the mechanical part of the process, and not sufficiently to the chemical principles upon which it should be founded. What now remains to be shown is the comparative position occupied by the colonial and beetroot sugar manufacturers, with reference to consumption and to commerce.

Firstly, then, with reference to the respective amounts of produce:

According to the official statements of the French Chamber of Deputies, respecting the beetroot harvests in nine Departments, it appears that

A maximum is obtained in the Département du Nord (the principal seat of the manufacture of beetroot sugar), where the produce amounts to 35,000 kilos. per hectare (= about 278 cwts. per acre).

A minimum in the Département Eure et Loire, where it only reaches 8,500 kilos. per hectare (= about 67.4 cwts. per acre).

The mean quantity (which very nearly corresponds with the produce in the Départements Aisne, Somme, Seine et Loire, and Seine et Marne) is 26,400 kilos. per hectare (= about 210 cwts. per acre).

The most abundant harvest, calculating the sugar at 10 per cent, would correspond to an amount of sugar=3,500 kilos. (= 27.8 cwts. per acre), of these, 7½ per cent, or 2,625 kilos. (about 21 cwts. per acre), are obtained from the manufacture as raw sugar.

The least amount of produce corresponds to an amount of sugar =850 kilos. (= 4 cwts. per acre), of which 637 (or 3 cwts. per acre) are obtained, and

The mean produce is equivalent to 2,640 kilos. (or 21 cwts. per acre), from which 1,980 kilos. (15.75 cwts. per acre), of raw sugar are produced.

Dumas states that the quantity of raw sugar (calculated for twelve months) amounts in mean to 3,600 kilos. per hectare (= 28.6 cwts. per acre).

The official documents state the amount of production of raw sugar in the French colonies at 80 millions of kilos. These are the produce, according to Lestiboudois, of 48,770 hectares. As a mean quantity, therefore, 1,644 kilos. of raw sugar are obtained from the hectare (or about 13 cwts. to the acre).

L. Wray calculates, upon sixteen years' experience in the East and West Indies and in the Straits of Malacca, the produce of an acre of land at 25 to 30 tons of sugar-cane, fit for pressing; the amount of sugar in the juice, at 20 per cent, on an average; and for every 11 parts of marketable sugar, 1 part of refuse (molasses, &c.) As, according to this view, by a good arrange-

rangement, 70 to 75, or even 80 per cent of juice can actually be obtained, the colonists ought to produce from a hectare:

Affording	With 62,780 kilos. of cane.		With 75,330 kilos. of cane.	
	Refuse.	Dry raw sugar.	Refuse.	Dry raw sugar.
70 per cent of juice	723 kilogrs.	8057 kilogrs.	888 kilogrs.	9659 kilogrs.
75 „ „	785 „	8632 „	941 „	10360 „
80 „ „	836 „	9208 „	1004 „	11050 „

or as the mean quantity of the above in cwts. to the acre:

Affording	With 549 cwts. of cane to the acre.	
	Refuse.	Dry raw sugar.
75 per cent of juice .	6.8 cwts.	79.5 cwts.

not the half of which they actually realize.

From these facts, it is evident that the real produce of beetroot culture, *i e.* the quantity of raw sugar per acre, which can be brought by its means into commerce, is only exceeded in the best situations by the actual amount of colonial produce (per acre); while in the mean, and in unsuitable situations, the amount of produce is equal. On the other hand, the absolute amount of produce from the soil (sugar in the cane), calculated upon the same surface of soil, and for equal periods of vegetation, is more than double in the sugar-cane than in the beetroot, the sugar-cane being relatively richer in the proportion of 18 to 10 per cent.

Possible extension of produce.—Although it must be admitted, that, with the spongy structure of the sugar-cane, it may never be possible to extract the 18 per cent of sugar so completely as the 10 per cent from the beet, yet it is very certain that a much wider field for extension is open to colonial industry than to the production from beetroot; for in the former, of the 18 per cent of sugar, 10 per cent are sacrificed at present in the process of manufacture; while of the 10 per cent in the latter, only 3 per cent are lost.

According to Boussingault, the culture of a hectare (2.471 acres) of beet requires the labour of a man for one hundred and thirteen days, and of a horse for thirty-five days; while the operations on an equal extent of sugar-cane land, as ascertained officially in framing the laws respecting sugar in France, absorb the labour of a negro for four hundred and twenty-five days. This waste of labour

might be saved by a better system of management; and to this prospective saving must be added the amount of fuel supplied by the refuse cane, which is nearly sufficient for all the operations concerned in the manufacture of the sugar; while the production of every 100 lbs. of beetroot sugar, in France, requires an expenditure of 40 lbs. of coal.

Although the production of sugar in the colonies is burdened with many and great, although not insuperable, impediments, which are partly attributable to custom and tradition, partly to indolence and ignorance, and partly to fiscal regulations; yet it cannot be doubted that it has great advantages over the manufacture of sugar from beetroot. The beet can only compete with the cane, under present circumstances, when a high import duty is imposed upon colonial produce.

The sudden abolition of slavery placed the whole relationship between the work to be done and the command of labour, which had been secured to the colonies by the negro population in a safe and efficient manner, at the mercy of a race of people naturally idle and given to pleasure, having no idea of regulating their labour of their own free-will, and living only in the enjoyment of the moment. The difficult period of transition to which that measure gave rise, appears, however, to have been happily surmounted, for the English colonists have exported from

1814 to 1834	(slavery still existing) . .	4,272,000 cwts.
1835 „ 1838	(time of apprenticeship) .	4,280,000 „
1838 „ 1846	(slavery totally abolished) .	4,089,000 „
1847	. . . . .	5,792,000 „

The following tables, for which we are indebted to the "Economist" journal, illustrate the extraordinary extension of the beetroot-sugar manufacture in Europe since 1828, while they convey some interesting information relative to the production of free and slave-labour sugar in general.

PRODUCTION OF SUGAR IN 1828.

I.—BRITISH POSSESSIONS.

	Tons.	
West Indies	210,500	
Mauritius	18,000	
British India	7,800	236,300

II.—FOREIGN FREE-LABOUR.

Java	5,000	
Mauritius, Siam, &c.	10,000	
Beetroot, Europe	7,000	22,000

III.—FOREIGN SLAVE-LABOUR.

Cuba and Porto Rico	65,000	
Brazil	28,000	
French colonies	50,000	
Danish and Swedish	10,000	
Dutch Guiana	10,000	
Louisiana	20,000	183,000
	Total	441,300

PRODUCTION OF SUGAR IN 1850.

I.—FREE-LABOUR.

	Tons.	
British possessions	260,000	260,000

FOREIGN FREE-LABOUR.

Java	90,000	
Manilla, Siam, and China	30,000	
United States, Maple sugar	70,000	
French, West Indies, and Bourbon	60,000	
Europe beetroot	190,000	440,000
	Total free-labour sugar	700,000

II.—SLAVE-LABOUR.

Cuba	250,000	
Porto Rico	46,000	
Brazil	110,000	
Dutch West Indies	13,000	
Danish	8,000	
Louisiana	124,000	551,000
	Grand Total	1,251,000

In France, where the manufacture of beetroot sugar was called into existence by the closing of the continent against foreign imports, this branch of industry was sensibly increased by the misguided policy of the French colonists demanding constantly an increase of duty upon all foreign colonial produce. In the year 1828, there were fifty-eight beetroot sugar manufactories in France. After the introduction of the high duty, on the 26th of April, 1833 (for French colonial sugar, from 38 to 70 fr.; for foreign, 80 to 105 fr., for the 100 kilos., according to the quality) their number rapidly increased. In 1835, they amounted to three hundred and forty-nine; in 1836, to four hundred and sixty-six; and in 1837, to five hundred and forty-two; producing altogether 45 million kilos., or $\frac{1}{3}$rd of the consumption at that period. A reaction ensued in the year 1838: a duty of 11 fr. per cwt. was levied on beetroot sugar at the place of production, and this was gradually raised to 27.5 fr. The number of manufactories diminished at once to three hundred and eighty-nine in 1840—41, and to three hundred and twenty-five in 1844, producing only 28 millions of kilos.

In countries like France, themselves possessing colonies, the sugar question gives rise to the most serious conflict amongst the interests of citizens entitled to equal consideration and protection. By protecting and fostering the manufacture of beetroot sugar, and thus discouraging colonial traffic, the state likewise runs the risk of impairing the efficacy of its only school for the supply of the Navy with competent marines. This objection is all-important to France, although of no consequence to this country, which only possesses three or four beetroot sugar factories. In the countries of the German custom's union the state of the beetroot sugar production is very flourishing, and has sprung up with surprising rapidity. In the year 1836, there existed only twenty-one factories; in 1838, these were increased to one hundred and fifty-eight; in 1841, however, only one hundred and thirty-six; and in 1845, only ninety-six remained. The decrease in the number of the manufactories does not here, however, indicate a diminution of production, but a concentration of industry, as duty was collected upon beetroot as follows:

In the year:	1841—42	1842—43	1843—44	1844—45	1845—46
Upon cwts.:	5,064,287	2,491,604	4,326,391	3,893,859	4,446,469

The geographical distribution of the beetroot culture is of

particular interest. Of the ninety-six manufactories of 1845, fifty-three belong to the Prussian provinces of Saxony (neighbourhood of Magdeburg) and Silesia, and twenty-four to the other Prussian provinces; while there are only nineteen in the other states of the union. These nineteen manufactories, in the year 1845—46, paid duty on 577,200 cwts. of beet only, and are on the decline like those of the other Prussian provinces; while the factories in the two first-named provinces are constantly on the increase. It appears, therefore, as the result of experiment, that there is only one district in the countries comprised under the commercial league, and that lying between Magdeburg, Brunswick, and Halle, which is adapted to the profitable culture of beet. The rapid increase of the beetroot sugar manufacture in the countries of the league, is likewise intimately connected with the tarif. According to the law of the 9th of May, 1841, the minimum duty on raw beetroot sugar was fixed at 20 per cent of the duty on foreign raw sugar. The beetroot consumed in the manufacture of raw sugar is the substance on which the duty is levied; and the law calculates, in fixing the duty, 3 cwts. of raw sugar from every 60 cwts. of beetroot, or only 5 per cent. This amount of produce is entirely erroneous, under present conditions, and the fixed duty is consequently illusory, for 7½ per cent of raw sugar are now obtained from the beet, only 13⅓ cwts. being required for the production of 1 cwt. of raw sugar, or 40 cwts. of beet for 3 cwts. of sugar. The manufacturer is only charged duty upon 3 cwts. of sugar for every 60 cwts. of beet; he produces, however, 4½ cwts. from that quantity, and consequently pays no duty on 1½ cwts. The intended amount of duty is therefore reduced from 3 to 2, and the protection augmented in an inverse ratio.

The 4,446,469 cwts. of beet, which were taxed in the year 1845—46, as affording 222,323 cwts. of raw sugar, and paid as many dollars duty, actually yielded 334,320 cwts. of sugar, and ought to have paid as many dollars duty. The revenue received, therefore, 112,000 dollars too little, or the actual duty upon raw sugar was reduced from 1 dollar to ⅔rds of a dollar. There is consequently no reason to complain, if the duty upon sugar is raised to keep pace with the improvements in its production.

Very remarkable results have resulted from a protective duty of this kind: a fine branch of industry, originally German, has been brought to a high state of perfection in a few years, and has

taken such deep root, that it has been able to profit by the technical application of science, and increase the production one and a half times. Thus a Prussian factory required to produce 1 cwt. of refined sugar:

In the year . .	1841.	1842.	1843.	1844.	1845.	1846.
	Cwts.	Cwts.	Cwts.	Cwts.		
Beetroot employed	27	$22\frac{1}{6}$	$19\frac{1}{4}$	$18\frac{4}{11}$	—	—
	Dollars.	Dls.	Dls.	Dls.	Dls.	Dls.
Affording . . .	19,000	1,750	6,250	26,600	43,000	52,000
	Loss.	Profit.				

Lastly, this branch of industry, so rapidly developed, has created a school for the manufacture of sugar upon scientific principles, the benefits of which have extended to the colonies, and produced the best results.

From a higher point of view, when the home production is viewed in reference to the entire consumption, the question assumes another shape.

Inasmuch as the sugar manufactured in the countries of the German League only yields from $\frac{1}{6}$th to $\frac{1}{7}$th of the entire amount consumed by the inhabitants, the simple result of the protection is to raise the price of sugar, or oblige the consumer to pay for a benefit afforded the producer. A high duty upon a necessary of life—for sugar must unquestionably be viewed as such—is equivalent to checking the well-being of the community in one of its main springs; and so much the more, as the duty weighs much more heavily upon the poor than upon the rich; the man with an income of £3000 per annum consuming more, but not thirty times as much as the man with an income of £300 per annum.

Raising the price of sugar is doubly obnoxious to the less wealthy classes, as this article of food is intimately connected with the use of another, that of coffee, which is one of the most indispensable requisites of those classes. In addition to these, the fiscal interests of the state must be considered: if, instead of the 334,320 cwts. of raw beetroot sugar, the same quantity of raw colonial sugar had been consumed, these would have yielded an import duty (at 5 dollars per cwt.) of 1,670,000 dollars., instead of 334,320 dollars; a deficiency, therefore, of $1\frac{1}{3}$ millions of dollars is left to be indirectly levied upon the consumers.

The question has moreover to be answered, whether the home

production of sugar offers sufficient advantages to make up for the diminution of traffic with the colonies which it occasions; and this question can only be answered in the negative. It diminishes the imports not only by its own amount, but considerably more, as by raising the price, the consumption is checked. This cannot be otherwise than prejudicial to the reciprocity of commerce, and to the exchange of the manufactures of the commercial league.

In the year 1846, the amounts of sugar of different qualities consumed in the countries of the league were—

1,363,143 cwts.,	valued at	13,640,072 dollars	= imports.
160,310 „	„	1,923,608 „	= exports.
1,202,833 „	„	11,716,464 „	= absolute quantity consumed, the population amounting to 29,460,816 persons: there are consequently consumed annually, per head,

In the countries of the league	4.08 lbs.	(at 0.5 kilo.) of sugar.
„ France	6.5 „	
„ Spain	3.5 „	
„ Holland . . .	14.5 „	
„ Belgium . . .	7.0 „	
„ Russia . . .	0.5 „	(not quite)
„ Ireland . . .	4.5 „	
„ England and Scotland	21.0 „	
„ the United States .	14.5 „	
„ Cuba	56.0 „	
Inhabitants of Venezuela	100.0 „	(according to Codazzi).

The consumption in the countries of the league is therefore comparatively very low, and would probably be increased two or threefold at lower prices.

The immediate advantages of the manufacture of beetroot sugar are confined however to a very small district, the $\frac{1}{80}$th, or at most the $\frac{1}{50}$th, of the entire territory of the commercial league. This district would otherwise produce corn, which is not too abundant in the country, as is proved by the years of famine which occur.

On the whole, therefore, it cannot be denied that the production of beetroot sugar in the states of the league is by no means a natural growth, but rests entirely upon an artificial basis.

It is a hothouse plant which adorns the country, but is purchased at considerable sacrifice by the whole community.

The following statement respecting the advantages of beetroot culture, in connection with the manufacture of sugar for Ireland, is taken from a pamphlet by Mr. Sullivan, of Dublin.

"In estimating the probable profit," he says, "I shall consider the quantity of beet employed in one establishment as 20,000 tons, used in a fresh state; and the product, as 5 per cent of white sugar, and ½ per cent of molasses:

EXPENSE.

	£
20,000 tons of beet, at 15*s.* per ton . . .	15,000
General expenses of manufacture, including management	9,000
Total . .	£24,000

PRODUCE.

	£
1000 tons of white sugar, at £1 8*s.* per cwt. .	28,000
500 tons of molasses, at 2*s.* per ton . . .	1,000
1000 tons of pulp, or 5 per cent of the roots employed, at £2 per ton	2,000
Total . . .	31,000
Deduct cost of manufacture	24,000
	£7,000

"Assuming capital sunk in buildings, machinery, &c., to be £20,000, and that the outlay £24,000 was unproductive for an entire year, the total capital on which interest would have to be paid, say at £5 per cent, would be £44,000; and reckoning wear and tear, taxes, &c., at 5 per cent on the whole capital invested, we shall have as follows:

Gross income upon capital embarked	£7,000, or nearly 16 p. c.	
Interest on £44,000 at 5 per cent, £2,200	£4,400	
Rent, wear and tear, &c., at 5 per cent, £2,200		
Balance . .	£2,600	

or nearly 6 per cent, equivalent to an absolute profit upon invested capital of 11 per cent.

This statement, as to what may probably be effected by the growth of beetroot sugar in Ireland, is further strengthened by a statement furnished by M. Paul Hamoir, of the firm of Serret, Hamoir, Duquesne, & Co., the largest beetroot sugar manufacturers in Valenciennes (April 18, 1850):

EXPENSE.

	Francs.	£
Cost of 60,000,000 kilogrammes (61,607 tons) of beet, at 16 francs (12*s.* 11*d.*) per 1000 kilogrammes (1 ton nearly) . . .	960,000	(38,400)
Cost of desiccation	300,000	(12,300)
General expense of manufacture . . .	690,000	(27,600)
	1,950,000	(78,000)

PRODUCE.

Estimating the percentage obtained at only 4½ per cent, 60,000,000 kilogrammes would give:

	Francs.	£.
2,700,000 kilogrammes (about 2,700 tons) of refined sugar, which, duty deducted, would be worth about 1 franc (9½*d.*), the kilogramme (2lbs. 3½oz.), or about 39*s.* per cwt.	2,700,000	(108,000)
Molasses, estimated at 3 per cent, 1,800,000 kilogrammes (1800 tons), at only 5 francs (4*s.* 0½*d.*) the 100 kilogrammes (about 220 lbs.)	90,000	(3,600)
Residue or pulp, at 1 franc the 100 kilogrammes	60,000	(2,400)
	2,850,000	(114,000)

This would leave a balance of £36,000, or double that deduced in my estimate.

"With the profits shown above, what has the sugar manufacturer in Ireland to fear from competition with West Indian, or other tropical sugars? The tropical sugar grown labours under serious disadvantages, of which the following are the principal: cost of labour, the difficulty of procuring manure, heavy freights, insurance, and loss from drainage, &c., the produce in the British

West India Islands having fallen from 4,103,746 cwts. in 1831, to 2,857,703 cwts. in 1845, in consequence of the rise in the price of labour caused by the emancipation of the slaves. The relative expense of cultivating beetroot in Europe, and the sugar-cane in the West Indies is thus stated by Boussingault. In Alsace, 1 acre of land sown with beet requires 45.6 days of a man, and 14.1 of a horse; in Guadaloupe, an acre of sugar-cane, which takes about 14 months to mature, would require 177 days of a man. The produce from the sugar-cane rarely exceeds 12 or 14 cwts. of raw sugar per acre, and even on the best lands is not more than 1 ton. But an acre of beet would yield 18 cwts., and require but 5 months to come to maturity, leaving the ground free for 6 or 7 months of the year, to take a winter crop of fodder from.

"The cost of bringing 1 ton of sugar from the West Indies cannot be under £6 or £7, which is saved to the beetroot sugar manufacturer.

"I think, also, that on examination, slave-labour will not be found cheaper than the same amount of free-labour in European countries. According to Boussingault and others, 1 acre of sugar-cane requires twice as much labour as 1 acre of beetroot. Now we shall find, on inquiry, that the one half of a labourer's wages is expended in food, and supposing food to cost in a tropical country only one half what it does here, the slave-owner is after all only on an equality, as he has to provide food for double the number of labourers. The European labourer has the remaining half of his wages to provide clothes, house, &c., and the slave-owner has to provide clothes, lodging, fuel for cooking; and in addition the capital embarked in the price of the slave, which is lost every time the slave dies. Even were they able to introduce processes which will enable them to double their produce from the canes, there is still margin for improvement in the beetroot sugar manufacture, and by improved agriculture, larger crops of beetroot may be raised.

"Further, in calculating the profit, I have assumed 28*s.* as the price of 1 cwt. of refined sugar, which is below the present price of foreign refined, and still is profitable. The price of refined sugar is now from 54*s.* to 55*s.* per cwt., and the duty on foreign refined, 22*s.* 8*d.*, deducting the duty from the lowest price, 54*s.*, we have 31*s.* 4*d.* as the price per cwt. of foreign sugar, 3*s.* 4*d.* more per cwt. than I have assumed for beetroot sugar. I also take the produce at 5 per cent, while by the new process 5½ can

be obtained, and I fully expect that 6 or 7 per cent will ultimately be obtained."

Baron Liebig, however, gives the following summary of the prospects held out to the two sources of manufacture.

"On an acre of the best land, for which a yearly rent of 50 florins (about £4 3*s*. 6*d*.) is paid, there is obtained, in the environs of Magdeburg, on an average, 10 cwts. of sugar, costing for its manufacture, besides wages, the price of 40 cwts. of coals. The beetroot contains 10 per cent of sugar, and of this 7½ per cent are obtained. The possible improvement, therefore, can only refer to the obtaining of 2½ per cent of sugar, now lost.

"An acre of land in the colonies, the rent of which is less than one-tenth of the rent in Europe, yields animally from 315 to 350 cwts. of sugar-cane (25 to 30 tons per acre—Wray), yielding 70 to 80 per cent of juice, in which are contained 20 per cent of sugar. The acre of land, therefore, produces, in the house of the sugar-cane, 40 to 50 cwts. of sugar, while the pressed residue furnishes nearly the whole, or the whole of the fuel necessary for the extraction of the sugar.

"For equal periods of vegetation, and equal surfaces, the absolute yield of sugar from the soil in the case of the sugar-cane, is more than twice as great as in the case of the beetroot.

"The makers of beetroot are in advance of the colonists in having better processes, that is, in saving labour; they have a climate better adapted to the working up of the juice; and they have, perhaps, in general, more intelligence. But that the manufacture of beetroot sugar continues among us at all, is owing to accidental circumstances, the duration of which is quite uncertain. The planters of the colonies are already infinitely better informed than formerly; an entire revolution in their methods has begun; they will cease to be negligent and wasteful. It is quite inconceivable that they should continue as hitherto, out of 20 per cent of sugar in the cane juices, to lose 12, and to gain only 8 per cent. The discovery of a simple means of preventing the fermentation of the juice in hot climates, and, as a consequence, an increased return of sugar, even to the extent of only 4 per cent, would suffice to render the manufacture of beetroot sugar in Europe impossible, economically speaking. It is for this reason that the latter has no future to look to."

Production of Sugar from other vegetable sources.

From Indian corn or maize.

In the year 1811, Dr. Ries instituted experiments upon the production of raw sugar from Indian corn, which were taken up, in the year 1834, by Dr. Pallas, in St. Omer. He obtained from the produce of 1 hectare of land, or from 3704 kilogrammes of stalks deprived of leaves, after the ripening of the fruit, 74 kilogrammes of raw sugar, or 2 per cent, and 148 kilogrammes of molasses.

Pallas maintained, in the year 1839, that the sugar diminished in the Indian corn stems with the formation of the fruit, and could consequently be increased by castrating the female flowers.

Burger is also of opinion that the amount of sugar attains a maximum immediately after the plant has flowered; an opinion which is rendered very probable by physiological researches.

Biot and Soubeiran were engaged upon this subject in the year 1842, and found, as was afterwards corroborated by Pelouze, that the juice of the Indian corn stalk contained principally cane-sugar, but also a certain quantity of another species of sugar. They found in a liter of juice from castrated stems, 10.66 grammes; in the juice of non-castrated stems, 11.79 grammes of cane-sugar; and they concluded from these results that castration is rather prejudicial than useful, and that it is better simply to pull the stems before the development of the fruit.

Indian corn is another species of the family of the grasses, which, like the sugar-cane, is characterised by a large amount of sugar. It thrives in much higher latitudes than the latter, is more easily expressed in consequence of being softer, and the period of its growth is much shorter, particularly when used prior to the formation of the fruit; so that in many districts two crops can be obtained in one year. These advantages it possesses over the sugar-cane; the earlier period at which it becomes fit to cut would also give it the preference over the beetroot, as the agriculturist is thus left more time to prepare the land for future crops; these advantages are however balanced by its containing another modification of sugar coexisting with cane-sugar.

According to the Statistical Agricultural Report of the Patent Office for North America, edited by Ellesworth, the amount of

sugar in Indian corn, the juice having a sp. gr. of 1.072 = 10° B., is equal to that of the sugar-cane, and three times as great as that of the beetroot. This is in contradiction to the well-known amounts of sugar in the two latter vegetables, and is obviously exaggerated.

1 acre (hessian) = ¼ hectare, will grow:

8,700 stems (according to Neuhold and Trautmann) in Austria.
12,521 stems, deprived of leaves in the blossoming season . . . . } according to Burger, in Steyermark.
9,740 lbs. of stems with ripe grains deprived of leaves . . . . . }
10,435 stems in Hungary, according to Ries, which weigh 5,217 lbs.

According to Burger, the 9,740 lbs. of stems afford 4,382 lbs. of juice, yielding 369 lbs. of syrup, of unnoted strength; the 12,521 stems, on the other hand, yield 1,556 lbs. of syrup.

According to Neuhold and Trautmann, 8,700 stems yield 7,131 lbs. of juice, from which 35 lbs. of crystallized sugar, and 70 lbs. of syrup are obtained. Dr. Ries calculates, on an average, 41 to 56 lbs. of sugar from an acre; Ellesworth, 617 lbs. (!)

The produce in stems of Indian corn, and the quantity of sugar obtained from them, is very variable in different countries; and the statements are altogether of such a character as to require further corroboration.

Sugar from the juice of the maple.

Several species of the maple—*Acer saccharinum, campestre, platanoides, pseudoplatanus;* further, the *Dasycarpum* (Ehrh.) *negundo, tartaricum,* and *rubrum*—all contain a colourless, sweet-tasting juice in their stems, of sp. gr. 1.003 to 1.006, which yields upon evaporation a syrup containing cane-sugar. In the latter four, it is of a dark colour and less pure; in the former four, it is of a wine-yellow colour, without any disagreeable taste; and the juice of the *Acer saccharinum* abounds particularly in sugar. There appears to be no other description than cane-sugar in the juice. These juices yield upon evaporation, in the order above observed, the following quantities of solid residue, according to Hermbstädt, 3.1—2.2—2.5 and 2.2 per cent. The trees affording the juice examined by him were from thirty to forty years old,

from 9 to 12 inches in diameter, and yielded in the spring between 75 and 100 lbs. of juice, containing from 3.1 to 4.7 per cent of sugar; thus from every tree from 3 to 5 lbs. of sugar could be annually drawn off.

According to Kalm, a maple-tree in Canada affords 155 to 310 lbs. of juice, the amount of sugar in which varies from 2.5 to 7 per cent; so that the sugar annually produced from a tree may not exceed 4 lbs., but can rise as high as 22 lbs.

Böhringer obtained 320 lbs. from a mountain maple, in Bohemia, one hundred and twenty years old; from another species of maple, (Spitzahorn) one hundred and thirty years old, 509 lbs. of juice, with 1.2 per cent of sugar; so that the first tree would yield annually 5 lbs., while the other would yield 6 lbs. of sugar.

Burger obtained from more than twenty maple-trees, tapped at different times and in different places in Styria, an average of 32.7 lbs. of juice per tree; the juice contained between 0.85 and 1.23 per cent of sugar.

It must still remain undetermined how far these discrepancies are attributable to the difference of locality or of growth, and how far to the different observers. The juice of the maple, however, can hardly be supposed to contain more than one-half of the sugar contained in that of the beet. The amount of water to be evaporated, before it can be made into sugar, is proportionally greater, and the apparatus for the manufacture more extensive. The beetroot comes to maturity in one season, while the maple requires the lifetime of a man; and, from the operation of tapping, is damaged after a few years, and dies. Lastly, the same amount of land will not yield nearly so much maple as beetroot juice. All these causes combine to prevent the maple from becoming a source for the production of sugar in Europe.

Production in America.—In North America, the relations, however, are very different. In the United States, in Canada, and the eastern countries, the maple is not only indigenous, but much more abundant than in Europe. It often constitutes whole forests, but is more frequently intermingled with other trees. Under these conditions, where fuel is a secondary consideration, and the value of land is of no moment, the production of maple sugar forms a regular branch of industry, particularly in countries which are far distant from the reach of tropical productions. The manufacture is of a wandering character, changing its locality

from year to year, but is said to produce annually from 7 to 12 millions of lbs. of sugar.

The natives were acquainted with this source of sugar before the countries were colonized by Europeans; they make incisions in the trees, and collect the sugar in dried grains, like resinous exudations. Europeans have introduced a more regular process of manufacture, upon which, as far as Canada is concerned, Kalm published a treatise in 1751. The process of manufacture is crude, like all forest operations, the producers being entirely dependent upon the woods, and forced to carry their implements and labour to whatever spot the raw material is most abundant. The implements are of the most indispensable kind: a few large awls or borers, $\frac{3}{4}$ of an inch wide, troughs for collecting the juice, wooden pipes of the diameter of the awls, through which the juice is drawn off; boiling pans, of the capacity of 60 or 70 liters (13 to 15 gallons); some casks, a few moulds; and, lastly, axes for clearing wood for fuel. The proper time of the year for collecting the juice is the month of February and the beginning of March, or the time when the flow of the sap is most abundant.

Two holes are bored on the south side of the tree, at a distance of 4 or 5 inches from each other, and 18 or 20 inches above the ground, in an upward, slanting direction, and not deeper than about $\frac{1}{2}$ an inch into the white bark or splint of the stem, that layer yielding the largest amount of juice. The juice is collected during about six weeks, towards the end of which period it flows more slowly and impure, and is less rich in sugar. It is conducted by the inserted pipes into the troughs placed below, and from thence by means of cans into a boiling hut, erected for the purpose, where it is placed in the reservoirs which supply the boilers. The juice cannot be preserved unboiled longer than two or three days, according to the temperature. The evaporation is carried on over a brisk fire, with constant removal of the scum, and the addition of fresh juice to supply the place of the evaporated water. The contents of the boiling pan, when it has attained the requisite concentration, is passed through a woollen cloth to separate the last portions of scum. The syrup is quickly boiled down in a similar pan, cooled, and filled into moulds to crystallize.

After the syrup has drained away, a solid kind of sugar

remains, dry in the grain, and pure in taste, which is not at all inferior to raw colonial sugar.

Maple juice is as free from foreign matters as that of the sugar-cane, and much purer than that of the beetroot. It evolves large quantities of ammoniacal vapours during boiling, and appears to contain no other variety than cane-sugar.

From gourds.

In the year 1834, some manufactories existed in Hungary for extracting sugar from the common gourd, *Cucurbita Pepo L.;* but the subject was more vigorously prosecuted in 1837 by a Hungarian, L. Hofmann, who took a patent for a new process of his own invention. He states that 26½ cwts. of gourds will yield 1 cwt. of sugar-flour, which corresponds to 3.77 per cent. A single gourd weighs from 1 to 1½ cwts., and some occur as heavy as 2½ cwts. An acre (=¼ hectare) will bear 348 to 390 cwts. of gourds, and will therefore produce from 13 to 14½ cwts. of sugar-flour.

The gourds are said to contain 82 per cent of juice, of 10° to 11° B. (sp. gr. 1.072—1.080), and to yield a species of raw sugar which is moderately coloured, and possesses a taste of melon; but is capable of producing refined sugar equal in quality to that from the sugar-cane.

Although the gourd is easily cultivated, and will grow upon indifferent or even bad soil, yet this branch of industry has been nowhere prosecuted except in Hungary.

From palms.

Different species of palms, as the Palmyra palm, the Coco palm, the Dwarf-fan palm, and the Wild-date palm, all of which are indigenous to the tropics, contain in their stems a juice charged with cane-sugar, which, in the fresh state, is an agreeably tasted liquid, and goes by the name of *Toddy*, in India. From this juice, *Arrac* is obtained, by vinous fermentation and distillation. By evaporating the toddy, a kind of raw sugar is produced in India, called *Jaggary*, resembling ordinary Moscovado sugar, which is consumed by the poorer classes of the Indian population. It is exported in mats or sacks, made of palm-leaves, chiefly from Ceylon, and is often adulterated with sand or earth.

Since 1841, some of the French colonists of Pondicherry have erected manufactories in Cuddalore, on the coast of Coromandel, where they prepare refined sugar, on a large scale, from jaggary, with the aid of lime, animal charcoal, &c., on the European plan, claying their sugar with rum or pure syrup. This refined palm-juice sugar, which is yellowish-white, and has the taste and texture of refined cane-sugar, is brought into the English market as colonial sugar, but is also known under the name of Date-sugar. The grain is said to be less firm than that of ordinary cane-sugar.

A very similar product, under the name of Date-sugar of Mogador (from the port of Morocco), is brought from the tropical regions of Africa.

Sugar from chesnuts, cactus, and affodil.

At the time of the continental blockade Spanish chesnuts were recommended as a source of sugar, and were said to contain 14 per cent. In the south of Europe and Algiers, the fruit of the *Cactus Opuntia* has been proposed for a similar purpose; and in Greece, a species of wild affodil (*Asphodelus*), with which experiments are said to have been made in Athens.

Saccharimetry.

The trade in sugar will only be established upon a sure footing when those interested in it are enabled at any time to obtain an accurate knowledge of the real intrinsic value of the raw material. The value of these goods consists, according to circumstances, either in the amount of saccharine matter generally, or in the amount of crystallizable cane-sugar, or in the entire quantity of both, which they contain. In other words, a test is very much required, or a means of accurately ascertaining this value readily, without any special experience or knowledge, and at an inconsiderable cost and trouble. A test of this kind would be most invaluable to the refiners, and for the collection of duties and imports. No part of the business of the refiner is of so great importance as the purchase of the raw material, since a knowledge of the quality of raw sugar can only be attained by long practice and experience. A person possessing a sound knowledge of the market, with only a superficial knowledge of the technical pro-

cesses of manufacture, will have a great advantage over the most able practical refiner, who is without experience in the purchase of raw sugar. It will also be quite impossible to preserve the integrity of the principle upon which the duty is levied, from frauds and the like, so long as the duty is levied upon the external forms and appearances of the produce, and, from the want of an accurate test, not on the real value of the article.

No method of ascertaining the real value of raw sugar has yet been discovered which fulfils all the necessary conditions; but the attempts to attain this object are so interesting and important, as to demand some short description; and it may be proper to state, that for all that has been done in this direction we have to thank the French, and more particularly the Société d'Encouragement, in Paris.

Barreswill's method.—The first saccharimetrical test was proposed by Barreswill, in the year 1844, and depends entirely upon the reaction of grape-sugar, discovered by Trommer (page 340). It consists in a quantitative experiment to ascertain how much of an alkaline solution of copper is reduced by a given quantity of sugar. Each specimen is examined by two trials. In the second trial, the cane-sugar is previously converted into grape-sugar by an acid. The difference between the two quantities of reduced copper indicates the amount of grape-sugar contained in the specimen. This process depends too much upon the skill of the chemist.

Payen's method.—The test proposed by Payen is simple and more practical, and has consequently been much more generally adopted. The principle is borrowed from a well-known test for saltpetre. It consists in a kind of refining process, on a small scale, and requires manipulations, to which the practical man is already accustomed; affording at the same time, from the similarity of the operations, direct indications of the character the sugar will assume when treated on the large scale. The specimen is washed with a saturated solution of pure crystallizable sugar. The loss of weight experienced by the washed specimen on drying, the amount of water evaporated, therefore, indicates the quantity of sugar that has been added by the solution. This quantity, deducted from that of the dry specimen, leaves a residue, which is equal to the produceable quantity of crystallizable sugar in the specimen. Tests of this kind are indeed only intended for the

refiner, and are not accurate for any other purpose, and inapplicable to syrups, solutions, &c.

Peligot's method.—In the same year, Peligot introduced a saccharimetrical test, founded upon the property of cane-sugar to combine in definite proportions with lime, forming a soluble substance which retains the alkalinity of the lime; and also upon the stability of this compound of cane-sugar with lime, at a high temperature, the corresponding compound of grape-sugar with lime being rapidly decomposed, under the same circumstances, into acids which neutralize the lime. In consequence of these properties, the discoverer endeavoured to convert the saccharimetrical into an alkalimetrical test, by digesting the sugar with an excess of lime, filtering off the compound of sugar with lime, and estimating the quantity of sulphuric acid requisite to neutralize a certain volume of this liquid (previously coloured with litmus). The lime is estimated from the quantity of acid employed; and from the amount of lime, that of the sugar. When grape-sugar is present, this is destroyed, as well as the alkalinity of the lime in combination with it, by boiling, and the test is applied a second time. The difference between the two results corresponds to the amount of grape-sugar.

Peligot's process appears to have been but little followed, although it contains the germ of an accurate and simple test, when perfected by a better arrangement of the practical details.

Optical test.—Biot has endeavoured to introduce an optical test for sugar, totally independent of the chemical saccharimetrical processes. Biot's experiments, which date from the year 1843, were brought to bear practically upon this point by the invention of the optical saccharometer of Soleil, in 1846; and this was improved in the same year, after Clerget had devoted much study to the accuracy of the instrument, as applied to chemical investigations.

It is well known that solutions of sugar possess, in common with rock-crystal, the property of producing circular polarization in a transmitted ray of light. Some varieties of sugar, like that of the cane, produce a deflection to the right; others, like grape-sugar, on the contrary, rotate the ray to the left. In all cases, the power of rotating a ray of light increases with the degree of concentration of the saccharine solution. If a ray of light traverses, under certain conditions, a plate of quartz in the polarizing

apparatus, the polarization of the ray is accompanied by the exhibition of certain colours: if a column of the saccharine solution be interposed, it will exert a certain influence upon the colours, which is the more marked the stronger the solution. The extent to which this influence is exerted, or the strength of the solution of sugar, is estimated by the thickness of the plate of quartz required to counteract it. The quartz plate is, therefore, constructed of two wedge-shaped pieces, which, when caused to overlap each other to a greater or lesser extent, produce a corresponding difference in their conjoint thickness. The saccharine solutions are compared by these means with a normal solution, containing 16,471 grammes of sugar to every 100 grammes of liquid, and forming a layer 20 centimeters in thickness.

A method depending, like the above, upon the passage of a ray of light, and the correct observation of tints of colour, requires, as a fundamental condition, transparency and absence of colour in the specimen to be examined, as well as an entire purity from foreign matters, which might exert a similar influence upon the ray of light. It is consequently only applicable to solutions of sugar of such purity as are seldom the products of practical manufacture. The necessity of presenting the samples for examination in this pure state, and the corrections and calculations that are rendered requisite to account for the modified effects produced by the foreign ingredients, are obstacles of the greatest magnitude to the general introduction of the optical test.

Specimens of molasses and solutions of raw sugar must first be decolorized by animal charcoal, and in this operation much sugar is retained by the decolorizing agent, and the strength of the original solution diminished.

The foreign matters contained in the sugar or saccharine juices may be altogether neutral in their action upon light. If, however, they likewise cause a deflection, this may be either to the right or the left; in the former case, the result of the observation will be augmented; in the latter, diminished. An indirect method overcomes this difficulty, and which is founded upon the fact, that none of these substances are affected in their influence upon light, by the presence of an acid; while the direction of the ray in a saccharine solution, when acid is present, is reversed, being from right to left.

A trial is therefore first made with the specimen itself, which is afterwards treated with acid. A new liquid is thus obtained,

the deflecting power of which is also measured. The difference between the two powers of rotation observed, affords then the result required. But here again another difficulty appears, for the rotating power of the transformed sugar varies with the temperature.

It therefore appears hardly possible to simplify these various precautionary measures to such an extent as to render the method practically useful to persons inexperienced in conducting scientific manipulations.

The optical test is, lastly, only calculated to indicate the actual amount of sugar in any product, and affords the practical man no information respecting the quantity of marketable sugar produceable from any given raw material; it can consequently never replace the test proposed by Payen.

APPENDIX.

ANIMAL OR BONE-CHARCOAL.

All the varieties of charcoal which result from the decomposition of organic bodies, possess the property of absorbing matters held in solution. Some varieties, as wood-charcoal, possess this property in a much less degree than others (as the charcoal obtained from nitrogenous matters). Animal charcoal (from flesh) like that obtained from blood, is too costly, and is in too fine a state of division, to be employed advantageously in the purification of sugar. Bone charcoal is, therefore, universally used in refineries, being obtained in coarse pieces of the shape of the original bones, and much cheaper than blood-charcoal prepared with potashes; it is nevertheless expensive, and its application materially affects the price of the sugar. Turners, glue-makers, phosphorus manufacturers, and agriculturists, all competing with the sugar-refiners for bones, naturally tends to keep up the price. To the agriculturist, however, the refuse from the sugar-house and the glue-works is nearly as valuable as fresh bone.

Bones.—The combustible animal matter (gelatinous tissues) of bones forms the smaller proportion of their substance; the larger proportion consisting of mineral substances, mostly *basic phosphate*

of lime, some *carbonate of lime*, a very little *phosphate of magnesia*, *fluoride of calcium*, *soda* and *chloride of sodium*, with traces of the *oxides of iron*, and *manganese*. The relation between the two kinds of constituents has been found as follows:

	Organic portion.		Inorganic portion.	
Ox bones	1	.	2	Berzelius.
	1	.	2.1	Marchand.
Human bones	1	.	2	Berzelius.
	1	.	1.8 to 2.3	Frerichs.
	1	.	2 in mean	
	1	.	1.6 to 2.2	Bibra.
	1	.	1.9 in mean	
Bird bones	1	.	2.3 to 2.6	

Although the bones of different animals, and indeed the bones of different organs of the same animal, are not precisely alike in composition. and the loose cellular portion in the interior of the same bone is somewhat richer in organic matter than the solid external part; yet, on an average, it may be assumed that bone is composed of $\frac{1}{3}$rd organic, and $\frac{2}{3}$rds inorganic matter.

Production of bone-charcoal.—When bone is exposed to a high temperature in close vessels, the organic matter is decomposed; the hydrogen, nitrogen, and oxygen, escape in combination with a portion of the carbon, as volatile empyreumatic compounds; while the remainder of the carbon, with the inorganic ingredients, are left as bone-charcoal, in the form of the original bone. Bone-charcoal is an essentially cellular substance, more porous in the centre than in the outer layers, but not massive in any part.

The decomposition of bones, and production of bone-charcoal, is therefore a similar process to the carbonization of wood, and the formation of wood-charcoal; it is, in fact, a carbonization of the bones.

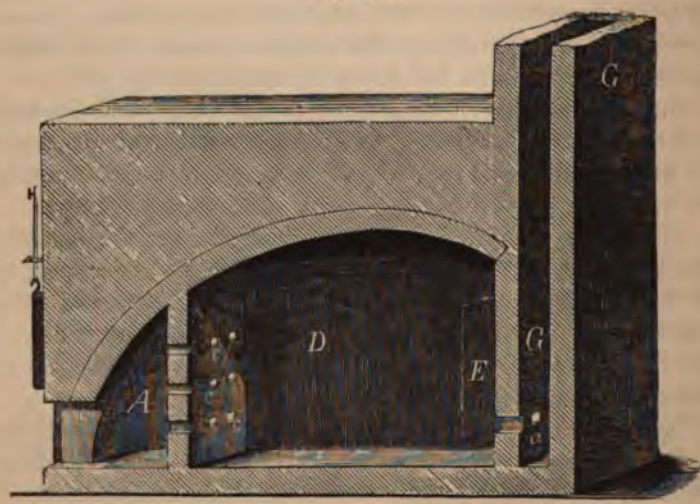
In the state in which bones are obtained from the butchers, knackers, and the kitchen, they contain a considerable quantity of fat, which is applicable for greasing machinery and other similar purposes. The bones are on this account first boiled, in order that the fat which then separates from them may be collected previous to their carbonization.

Bones are carbonized either with the double object of obtaining empyreumatic products, such as tar, &c., as well as bone-charcoal, or the latter product is the only object in view.

In the former case, the carbonization is carried on in retorts, precisely similar to, only somewhat larger, than those employed for distilling coal in the manufacture of illuminating gas. The bones are placed in cylindrical iron retorts, from which the empyreumatic products are condensed and collected, by means of pipes, cooling apparatus, and receivers. These products are valuable on account of the large amount of ammoniacal compounds which they contain. This method of distillation, which was first introduced by Payen, involves a larger consumption of fuel than the other methods of charring described below, and the charcoal obtained has been found by experience to be of inferior quality. These two circumstances combined are more than sufficient to counterbalance the value of the empyreumatic matters; and it has been found more advantageous, as in the respective manufactures of gas and coke, to separate the two objects from each other, and allow the empyreumatic matters to burn away in the production of bone-charcoal.

Charring in pots.—The bones, previously broken up that they may pack closely and occupy less space, are placed in iron pots especially cast for the purpose, or in short cylinders. These pots are placed in pairs, in the body *D* of the furnace represented in Fig. 126, through the door *E*, care being taken that they are so arranged as to allow the flame thoroughly to circulate among them, as it issues from the fire-place *A* through the apertures

FIG. 126.



c c c. The draught passes through the flues *a* into the chimney *G*. One pot is inverted over the other, and the crevices between them filled up with clay.

The clay in the crevices between the pots soon contracts, and numerous cracks are formed, which allow the empyreumatic vapours, evolved at a red heat or before, a free exit into the body of the furnace *D*. These vapours immediately take fire and burn, and the carbonization is carried on from that time as much by the heat which they evolve as by the heat produced from the fuel in *A*, while a corresponding saving is thus effected. As soon as the evolution of vapour ceases, or when the heat attains full redness, the combustion is at an end; the fire is then extinguished, and the oven closed and allowed to cool, that the pots may be removed and emptied through the door *E*.

Upright furnaces may be substituted for the horizontal ovens, as in burning lime or bricks. Both afford good charcoal, but it is impossible to prevent a small portion of the charcoal in the neighbourhood of the cracks being burnt to ash, in consequence of the admission of air at those parts; and this being useless for decolorizing sugar, must be disposed of for other purposes. The saving in fuel, on the one hand, is much diminished; on the other, the necessity for allowing the oven to cool between each operation, occasions a loss of the heat accumulated in the red-hot walls. The combustion of the vapours also is never complete, and the intolerable penetrating odour which they evolve to the annoyance of the neighbourhood can never be entirely avoided.

Lastly, the cast-iron pots are rapidly destroyed by the formation of oxide, which peels off, and is constantly reproduced. Clay pots are expensive, from their great liability to crack; while charring in the body of the furnace is not advantageous, as with the most perfect regulation of the draught, the greater portion of the charcoal is always burned to a white ash.

In order to destroy the smell, which in populous districts is an absolute necessity, the gases, instead of being burnt at once, are, according to a plan proposed by Darcet, mixed with air, and carried through the fire. In this manner, they are completely destroyed, and the gases passing off from the furnace have only a slight smell of sulphurous acid.

The construction of apparatus to work continuously has been repeatedly tried, but without uniform success.

The pots described above contain about 25 lbs. of bones, and

yield 13 lbs. (=52 per cent; 55 to 60 per cent, according to Otto) of bone-charcoal. This amount of produce appears small, when compared with the composition of the bones, and is attributable to the moisture and impurities which they contain. If pure and dry, they should yield 20 lbs. of charcoal.

Granulation of the bone-charcoal.— All the mechanical contrivances which afford much dust, such as mills with horizontal or upright stones, are not adapted for the granulation of bone-charcoal. The grinding machinery must be of such a character as to protect the coarser particles from being converted into fine powder, and this can only be done in mills with grooved rollers. The hopper into which the bones are thrown is a long quadrangular box, furnished at its lower aperture with moveable steel cheeks, between which a sharply grooved roller revolves. Between these cheeks and the roller, the bones are coarsely broken up, and fall in this condition upon a pair of bluntly grooved rollers, which complete the granulation. The latter can be placed nearer or further from each other at pleasure. The crushed charcoal is collected on sieves, which separate the dust from the proper sized grains; the coarser particles are returned again between the rollers.

Perfectly dry bone-charcoal consists in 100 parts; of 10 parts charcoal, and 90 parts bone-earth, of which about 6 parts are carbonate of lime.

Properties of bone-charcoal. — Bone-charcoal, like all other varieties of charcoal, but more particularly animal charcoal, is remarkable for the property which it possesses of condensing gases in its pores, and attracting to itself, and separating, various solid and liquid substances from solution. The manner in which this action is exerted upon matters in solution is particularly interesting with reference to the purification of sugar.

It was formerly the general opinion—and appearances seemed to corroborate the idea—that this action of animal charcoal was only exerted towards bodies of organic origin, particularly colouring matters, bitter and aromatic bodies, as turmeric, litmus, indigo, the red colouring matter of wine, the brown colour of the crude saltpetre leys, sugar syrups, the bitter principle of aloes, wormwood, &c.; also noxious vapours from bodies undergoing putrefaction, empyreumatic oils, oil of grain and potatoes produced during fermentation, different volatile vegetable oils, &c.

Graham afterwards found that inorganic substances were equally subject to this action of charcoal, and proved that charcoal ab-

stracted the lime from lime-water, and completely absorbed the basic metallic oxides, particularly those of lead, also ammonia and potash, from solution in water. It exerts a less energetic action upon neutral salts. According to Chevallier's experiments, neutral acetate and nitrate of lead are entirely absorbed by washed or unwashed animal charcoal. The acetate is more easily absorbed than the nitrate. The absorption requires (with from 1 to 10 parts of charcoal to 1 of salt), in the cold, from one, two, to six days; and at the boiling temperature, from two to five minutes. The salts of lead were completely absorbed, when dissolved in water, alcohol, or acetic acid; while from a hydrochloric or nitric acid solution the lead was never entirely removed.

According to Graham, the iodine even is separated from iodide of potassium. Weppen's experiments appeared to prove that the action of the charcoal extended to all metallic salts, and with the following salts no doubt remained of this being the case, viz.: the sulphates of copper, zinc, chromium, and protoxide of iron, nitrates of nickel, silver, cobalt, suboxide and oxide of mercury; also, with acetate of lead, tartar emetic, protochloride of tin, corrosive sublimate and peracetate of iron.

In the precipitation of these salts by charcoal, three cases may occur: the salt is either absorbed unchanged, or a basic salt is precipitated upon the charcoal, or the oxide in the salt is reduced to the metallic state. Some metallic acids, as antimonic and tunstic acids, are precipitated from their potash or ammonia-salts, although no effect was produced upon arsenite or arseniate of soda. The salts, containing an alkali as base, are little affected. Free acids either hinder or prevent the precipitation of the metallic oxides, which action, however, is independent of the lime contained in the charcoal. The substances absorbed are deposited unchanged on the surface of the charcoal, as can be easily proved by redissolving the colouring matter of indigo absorbed by the charcoal, by means of potash. The charcoal, however, acts chemically upon the substances, in the course of time, probably in consequence of the intimate contact which occurs; thus, for instance, oxide of lead becomes in time reduced to the state of metal.

As a summary of the existing observations, it is obvious that the absorbing power of charcoal is exerted, if not upon all, at least upon a great number, of the most different chemical compounds; but that it varies in intensity, according to their chemical composition. It appears, therefore, that the reaction is in general only

of a mechanical nature, which is however, in some cases sufficiently powerful to overcome chemical affinities of considerable power.

The power of absorption here referred to is not peculiar to charcoal, but is shared by all solid substances, and is dependent on the attraction exerted between their surfaces and the bodies dissolved, whenever the surfaces are capable of being moistened by the solvent. A drop of red wine, allowed to fall upon a tablecloth, produces a stain which is only red in the centre, but colourless at the circumference, the first portion of the cloth touched absorbing all the colouring matter, and only colourless wine spreading out by capillarity. All kinds of woven goods and paper exhibit the same reaction, upon which indeed the art of dyeing is founded.

The power of absorption in the varieties of charcoal is so much the more developed and apparent, in consequence of the extraordinary extent of acting surface which they present, either on account of a great degree of division as in blood-charcoal, or from their porosity as in wood- and still more in bone-charcoal.

The extent of surface is difficult to measure exactly, but some idea may be formed by calculation. Supposing the pores or cells of the bone-charcoal to be regular cubes of equal size, and $\frac{1}{500}$th of a line in linear dimensions (*i. e.* the diameter of a grain of starch of medium size), the cubic inch in all the three directions will then be divided by 500 partitions, and will consequently present an entire surface (omitting the thickness of the walls) of 3,000 cubic inches. The charge of charcoal contained in one of Dumont's filters (Fig. 125) amounts to 5,376 cubic inches, which, upon the above supposition, would present a total surface of 160,000 square feet (hessian) =10,000 square meters, or 4 hessian acres =1 hectare=2.471 English acres.

Action of charcoal in the process of sugar refining.—There are some observations with reference to the interesting action of bone-charcoal on the substances contained in saccharine juices, which require special notice. On filtering the defecated juice, different substances, such as sugar, gum, mucus, and other organic matters, salts of lime and the alkalies, in combination with organic and mineral acids, besides caustic lime, are simultaneously brought into contact with the charcoal; and the question arises as to what will be the result.

When juice of this character is allowed to flow upon a moist and firmly-compressed charcoal filter, pure water is the first pro-

duct that passes through; but a considerably larger quantity is obtained than was employed for moistening the charcoal. Water is then obtained of a decidedly saline character, which increases in strength; and after this has passed through for some time, a sweet taste becomes perceptible, which gradually increases, and at last entirely masks the saline. This purely sweet fluid continues to flow for some time, when it at length begins to acquire an alkaline reaction from the presence of caustic lime, and this reaction rapidly increases in intensity. Some time after the appearance of this reaction, a slight colouring of the filtered liquid may be observed, which continues, until the colour, constantly becoming deeper, is at length as dark as when the liquid was first thrown into the filter, and then the action of the charcoal entirely ceases (Lüdersdorf).

These phenomena explain themselves. They prove that the attraction of the charcoal for the saline ingredients ceases much sooner than the attraction for the colouring matters, but that the absorbent action is exerted upon all the ingredients of the liquid. The inference which Lüdersdorf drew from the fact, that the charcoal relinquishes one class of absorbed substances for others, to which it shows a preference, does not appear well founded.

The absorption of lime by charcoal has been more intimately studied by Schatten. He found that the caustic lime itself, whether dissolved in water or in saccharine juice, was taken up by the charcoal. The power of absorption for lime is affected by many circumstances; a temperature of 75° C. (167° F.) increases it in the proportion of three to four. Time also is of importance, for, under similar circumstances, twice as much lime is absorbed in twenty-four hours as in half an hour. When twice as much lime-water is acted upon by the same quantity of charcoal, one and a half times as much lime will be absorbed in the same time. The same quantity of charcoal treated repeatedly with lime-water, and washed and dried between each separate operation, the absorption was observed to diminish in proportion as the charcoal became saturated with lime. Thus, 100 parts of bone-charcoal absorbed in the first treatment with juice of the beetroot 1.63 parts, in the eleventh treatment, 0.51 parts, or 3.2 times less; and the total quantity absorbed in the eleven operations was 6.26 parts.

By heating once-used bone-charcoal to incipient redness, its decolorizing power is increased, but not its power of absorbing

lime. The latter property is also much diminished in intensity, when the charcoal is only washed and boiled without being dried. The natural amount of lime in the charcoal (*i. e.* the lime combined with phosphoric acid) exerts considerable influence. Bone-charcoal, containing 5 per cent of lime, absorbed twice as much lime as charcoal containing 9 per cent. Charcoal, entirely free from lime, absorbs five times as much lime from beetroot juice as charcoal containing 11 per cent of lime. Bone-charcoal absorbs carbonate of ammonia from the atmosphere, but this appears to affect its power of absorbing lime to only a small extent.

The organic matters which remain in solution after the clarification of the juice, and are precipitated by basic acetate of lead, are very little absorbed by the charcoal (to the extent of about 0.1 per cent, with 20 parts of charcoal to 100 of juice). Bone-charcoal has not the slightest action upon gum-arabic.

Revivifying animal charcoal.—Theory and practice prove that the power of absorption in animal charcoal is limited, and very soon exhausted. This exhausted power may however be entirely or partially renewed in the charcoal by different means; and, in an economical point of view, this is of the greatest importance to the sugar manufacturer, wherever Dumont's filters are in use.

The following different methods of revivifying the charcoal have been adopted—*heating to redness, washing, fermentation,* and *steaming.*

In forming an opinion upon the relative value of these methods for renewing the power of the charcoal, it must be borne in mind that the charcoal is required to remove both colouring matters and lime, and that both the one and the other must be removed in order that the charcoal should regain its entire efficiency. If the absorbed organic matters are destroyed by heat, they leave a residue of vegetable charcoal in the pores of the animal charcoal, which gradually stops them up, while the lime remains untouched. Heat alone, therefore, is inadequate thoroughly to renovate the charcoal.

Abroad, the renovation of the charcoal, with some unimportant variations in the methods of carrying it out, consists in submitting it to fermentation, washing (first with muriatic acid or at once with water), drying, and subsequently heating to redness. In reburning the charcoal, the pots may be dispensed with, as the requisite degree of heat is much lower than that originally re-

quired, and the danger of burning the charcoal to ash is proportionally diminished. In France, the process is carried on in reverberatory furnaces, with a flat arched roof, the doors of which however are made very close. In Magdeburg, narrow cylinders or wide tubes, fitted with a lid at the top, and a sliding door below, are used, several of which are placed in an upright position, in a reverberatory furnace.

There is a great advantage in submitting the charcoal to fermentation previous to burning, as the greater portion of the absorbed organic matters are destroyed in the pores with the evolution of gas, while a very small quantity remains to be charred; but, on the other hand, it is attended with the disadvantage of giving rise to carbonic acid, which converts the lime into carbonate, and renders it more difficult to remove; for although the fermentation becomes at last acid, or even when muriatic acid is employed for washing, the action of these acids is restricted to the surface of the grains, the pores being previously filled with carbonic acid. The best process is consequently that proposed by Schatten, and carried out at Magdeburg, which consists in pouring dilute muriatic acid upon the charcoal as it leaves the filters, and before the lime has been able to absorb carbonic acid; the acid acts at once with great energy, and becomes completely saturated with the evolution of much heat. The charcoal, upon this plan, is let down into large reservoirs, and water is poured upon it, containing, to every 100 quarts, 1 lb., or something less than ½ per cent of muriatic acid. With this water, the acid in which becomes saturated in half an hour, a lively fermentation ensues, which lasts eight days. The water from the fermentation having been removed, and its place repeatedly supplied with fresh water for washing, the charcoal is treated in smaller vessels with water containing some muriatic acid, until the lime is thoroughly saturated, when the charcoal is again washed, and then heated to redness. Any excess of acid must be carefully avoided, as it would attack the phosphate of lime, soften the charcoal, and thus render it useless. The upper layers of charcoal in the filters, which first come into contact with the juice, are six times as much impregnated with lime as those below.

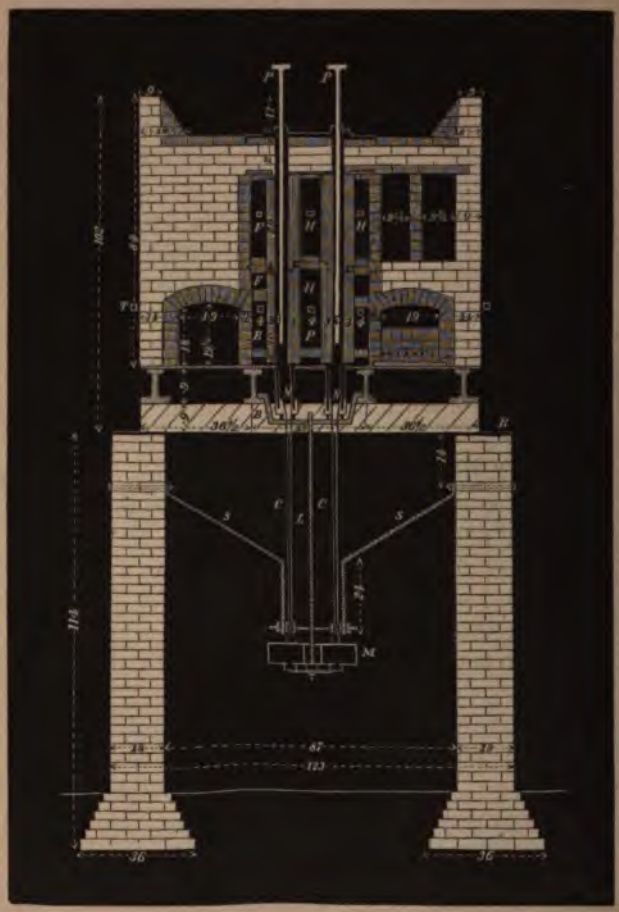
By treating the exhausted charcoal with steam, at a very high temperature, which has been tried on an extensive scale, the decolorizing power of the charcoal is said to be very completely restored; but the statements upon this subject require more con-

firmation. It is obvious that no loss could be sustained in this process, but at the same time the lime cannot be removed.

According to Payen, bones which have been used for preparing glue or gelatin soup, and are thus deprived of their organic constituents, can be made into bone-charcoal, which is not inferior to that from the entire bones, provided the bones be impregnated with coal tar previously to being carbonized.

Fig. 127 is a section of the charcoal reburner, used by many of

FIG 127.



the London bone-charcoal makers, and which was patented some years ago by Mr. Parker, to whom we are indebted for the sketch.

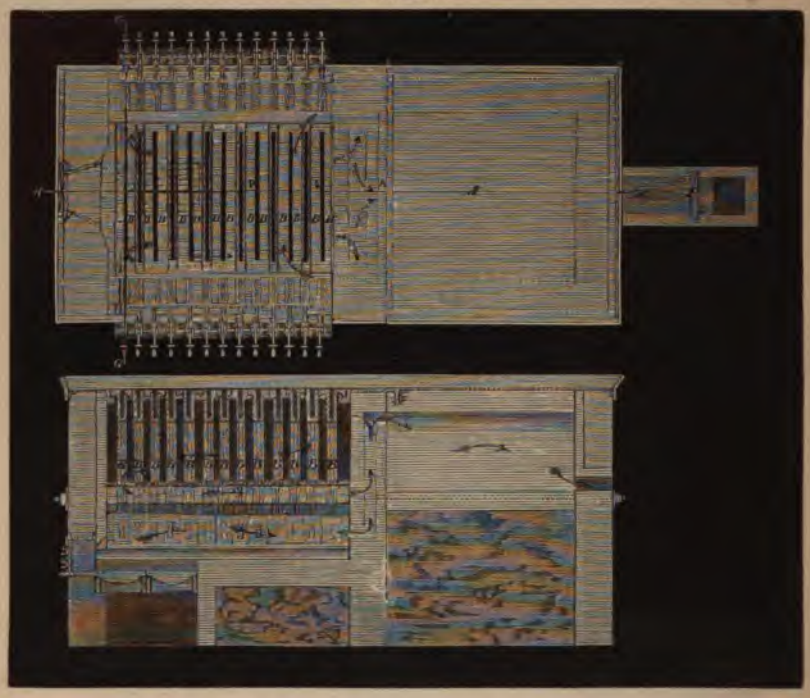
Narrow spaces constructed of fire-brick, the bottoms of which are indicated in the Fig. at *N*, are surrounded by the flames from a fire passing through the flues *B*, *F*, and *H*, which retain them at a low red heat. These narrow upright brick retorts are connected in an air-tight manner below with the still narrower sheet-iron receivers or coolers *C C*, into which a certain quantity of the reburnt charcoal can be allowed to fall at stated intervals, and become cool without the access of air. It is ultimately removed from below, passing through the measurer *M*. The reburners are open at the top, where the charcoal is admitted, and piled up in a heap above the aperture; so that, as one portion is removed below, its place is immediately occupied by a portion falling down from above. *P P* are tubes, through which the temperature in the interior of the charcoal can be observed, and which serve at the same time as an exit for the gases evolved in the lower parts of the reburners.

Figs. 128 and 129 represent the reburning apparatus of Messrs. Pontifex and Wood, the result of their extensive experience.

FIG. 128.

The charcoal that has been used in the filters, after having been washed in a cistern, is taken out and laid aside to allow the water to drain from it; it should then be removed to the reburner, and placed on the wrought-iron plate *A*, which forms the back part of the top of the reburner; the fire having been lighted, the plate will become hot and thoroughly dry the charcoal before the retorts *B B B*, *B B B B* are heated. When the charcoal is thoroughly dry, it should be raked forward into the retorts, filling them up, and heaping up the charcoal over them to a height of at least 6 inches or more. After the retorts are thus charged, a red heat is applied during fifteen to twenty minutes, after which the operation is finished. At the expiration of this time, the slides *a*, in the boxes *C C*, are opened, which allows the charcoal, contained in the pipes *D*, and a portion of that in the retorts, to run into the boxes *C C*; the slides in the boxes are then closed, the charcoal from

FIG. 129.



the top and over the retorts descends, and the hollows in the heap over the retorts are supplied from the charcoal on the plate *A*.

The slides *E E*, at the bottom of the boxes, are now opened, the contents of the boxes having become cool, and the charcoal is run into trucks or boxes, as the case may be, placed below the boxes *C C*, when a little water should be thrown on the charcoal to reduce the temperature; and the charcoal may then be stowed away, ready for use. The first charge is never properly burned in this apparatus, a portion having been left in the pipes *D*, which are below the heat of the fire; this first quantity must therefore be thrown again on the top of the retorts. After the apparatus is once at work, a charge may be drawn every fifteen or twenty minutes, according to the temperature, which is regulated by the damper *F*.

The fire in this arrangement should never be put out, since the cooling of the retorts soon destroys them. They may be worked at any velocity, by allowing a greater or lesser draught; but the

charcoal must never be allowed to become red-hot above the tops of the retorts, where it is in contact with the air. If the charcoal is properly heaped up over the retorts, and the charge drawn regularly, the apparatus works remarkably well.

The receptacle *C*, into which the charcoal is let down when it is sufficiently burnt, is divided into as many compartments as there are retorts, and each compartment holds half the quantity burnt in one of the retorts, the corresponding receptacles on the other side of the apparatus holding the remainder. The valves *a* are flat plates of cast-iron working in grooves, and are intended to open or close the communication between the retorts and the receptacles for the burnt charcoal. They are worked by the handles abutting on each side of the plan. Messrs. Pontifex originally constructed this valve of a flat plate of wrought-iron, reaching to the end of the set of retorts, with alternate perforations to fit the bottoms of the retorts, so that, by drawing it out three or four inches, the communications of all the retorts with the receptacles were simultaneously opened; but it was found that so long a plate of thin iron was liable to warp with the heat, and therefore separate valves for each retort were substituted. This long perforated slide is, however, used for letting the charcoal out of the receptacles into the trucks for conveying it away, as the heat is not sufficiently intense to cause any danger of the valve warping.

In the longitudinal section of the reburner, a section is shown of the whole of the retorts cut across in the middle, on the line of the union of the two legs of the retorts; and consequently it shows the end-sides of the retorts slanting towards these legs or breechings, as they are termed.

The transverse section shows the retorts cut across the middle, at right angles to the longitudinal section. There is an iron dish on the top plate, which covers and binds the retorts together; the front part of this plate is perforated over the retorts (as shown in the plan), which are charged through these perforations. The back part of this dish acts as a drying plate, the charcoal being placed upon it previously to being raked forward into the retorts, and consequently becomes thoroughly dried before being burnt.

The direction of the flues is shown by the arrows on the drawings. Each retort revivifies 50 lbs. of charcoal every fifteen or twenty minutes, and consequently the burner revivifies about $9\frac{1}{2}$ cwts. at least of spent charcoal per hour.

Substitutes for bone-charcoal.—Of the substitutes which have been proposed for bone-charcoal—none of which, however, are of equal power—the best is the charcoal obtained from bituminous shale. This mineral is constituted, like bone, of an earthy and an organic constituent, and yields a similar charcoal. The rare occurrence of the substance places it beyond the reach of most manufacturers, and the capability of its decolorizing properties being restored by the aid of muriatic acid is very questionable.

Another substitute is known under the name of *carbon*, and is obtained by charring molasses. The large quantity of salts, and particularly of alkaline salts, in molasses, which must be relatively increased in the charcoal obtained from it, are not in favour of the efficacy of this substance.

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THE END.

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EXPLANATION OF THE PLATES.

Plate I. represents the vacuum pan.

Plates II. and III. represent the mode of working the discharge cocks to the vacuum pans.

Plate IV. represents the plan, and Plates V., VI., and VII. the elevations, of the arrangement of machinery on the system of manufacturing pure refined sugar direct from the cane-juice, adopted and erected by Messrs. Pontifex and Wood, the details of which have been described in the foregoing pages.

Plate V. is a sectional elevation through the line *Z Z* on the plan.

Plate VI. is a sectional elevation through the same line, but looking the opposite way.

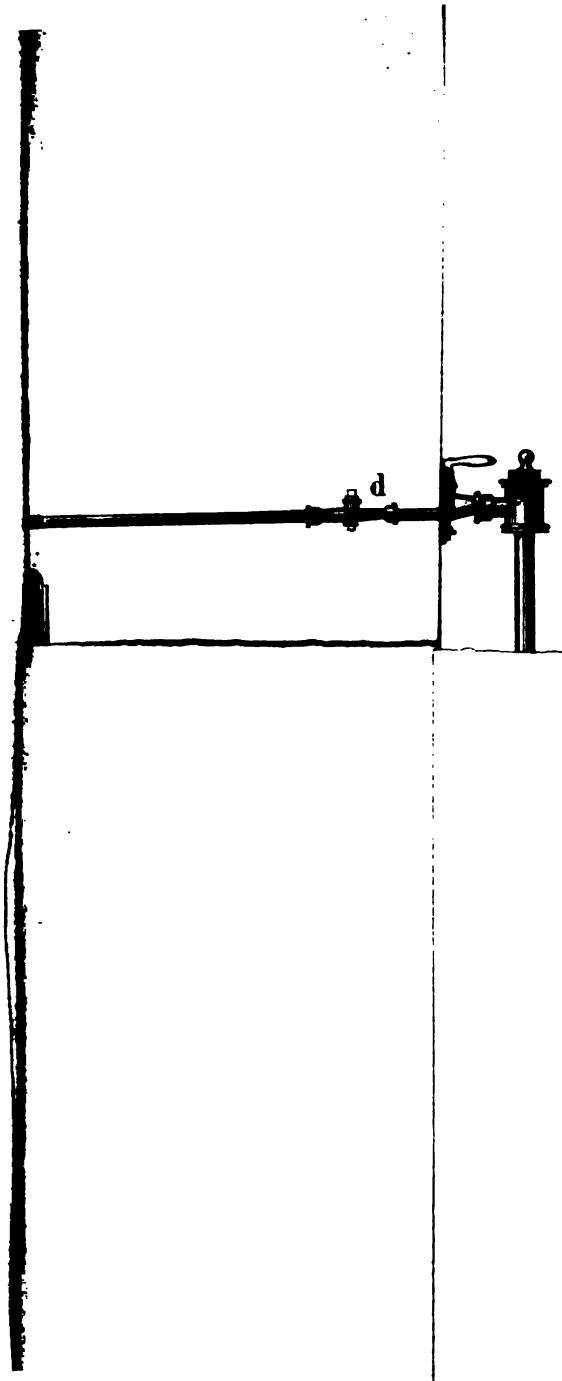
Plate VII. is an elevation through the line *Z' Z'* on the plan.

The subjoined letters in the description of these drawings are applicable to the whole of them.

A A are the boilers, for supplying the whole of the manufactory with steam. Trash being used as the fuel in these boilers, the fire-place is placed underneath them; the flame passes below the boilers to the end, returns through the two flue tubes in the boilers, and finally passes along the side flues to the chimney. If coal is to be used as fuel, the boilers should have only one flue tube, with the fire inside it. Simplicity of construction is of the highest importance in colonial boilers. Complicated ones are likely to require repair oftener, and it is not easy to get this properly done.

B B are the mills for expressing the juice from the canes. They are driven by the high-pressure engine *C*.

The juice passes from the mills through the copper gutter *a* to the cistern *D*, from whence the monte-jus *E* raises it to the cistern *F*. From thence the juice is run into such of the clarifiers *G* as are intended to be used, by means of a pipe running the whole length of



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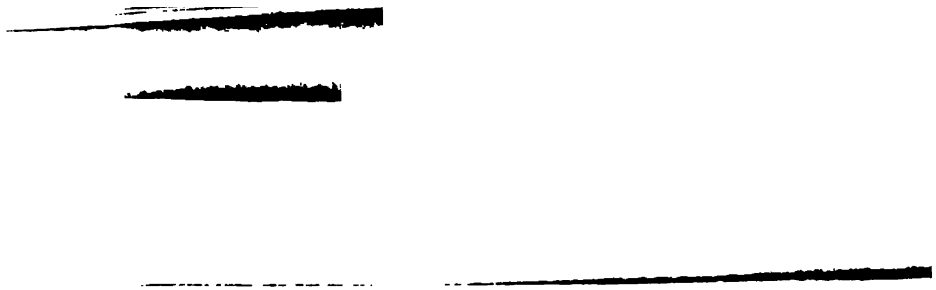

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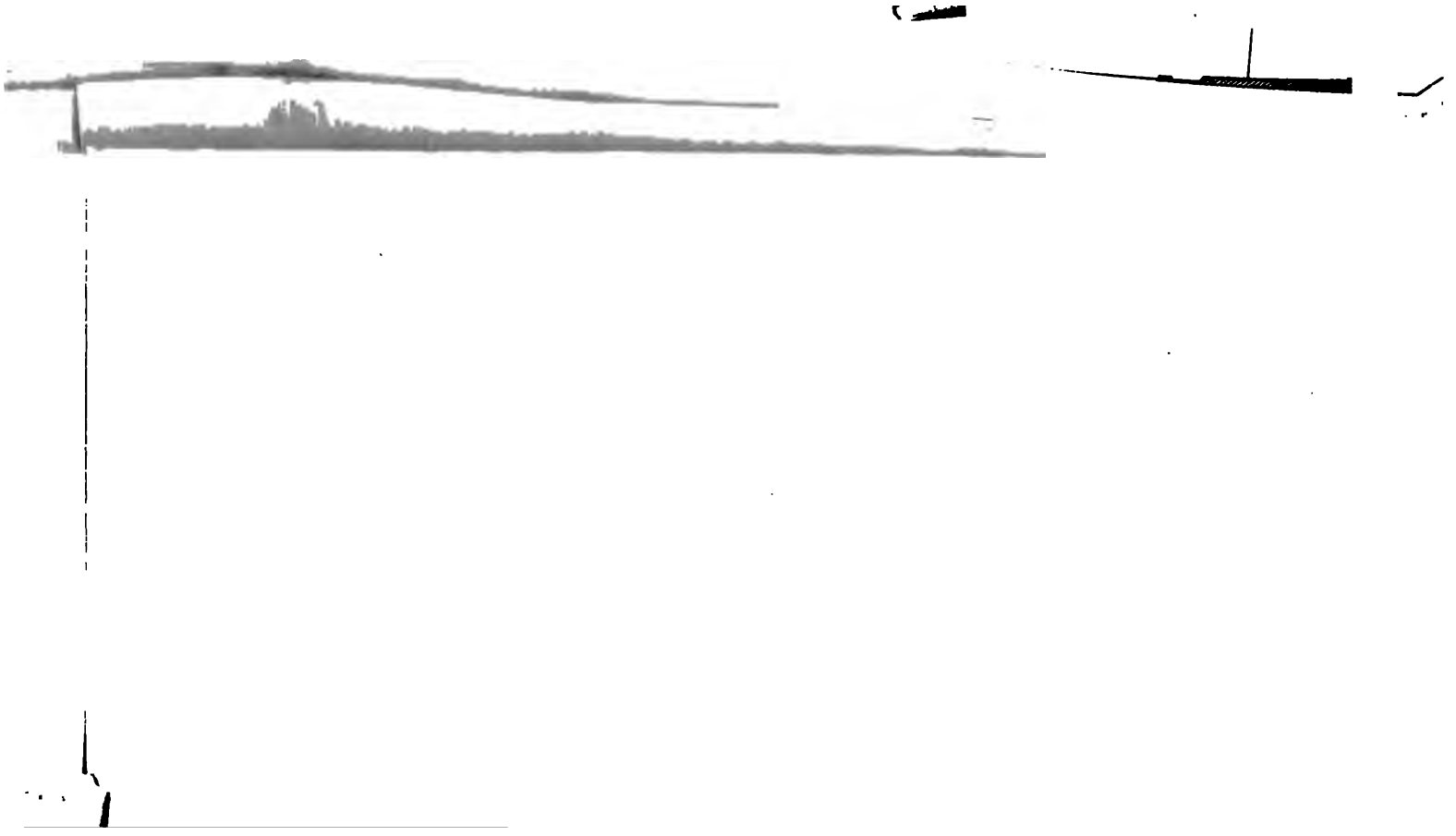


the range, with a cock over each clarifier. The operation of clarification is still progressing in some of these vessels whilst in others it is finished, some are being filled and others emptied, whilst others again are being cleaned out. Several of these clarifiers are therefore requisite to allow for those that are thus temporarily thrown out of use.

For the same reasons, an apparently large number of charcoal filters are required.

The juice, when clarified, runs through the smaller of the two ways in the cock under each clarifier, along, consecutively, the gutters *b c* and *d* to the bag-filters *H*, and the combination filters *I*. Both descriptions of filters are shown in these drawings, this set of machinery having been constructed with a view to test which would best answer the purpose. The combination of wire-sieve and bag-filters has the advantage that the sieves, by first abstracting the coarser impurities, leave the flannel bag suspended under each of the bottom sieves freer to separate the finer matter.

From these mechanical filters, which are heated by steam, by means of the small pipe *e*, the juice passes along the copper pipe *f* to the charcoal filters *K*.

After passing through the charcoal, the filtered juice runs through one of the gutters at the foot of the filters into the cistern *L*, and is thence pumped by the engine into the cisterns *M* and *M'*, which are for supplying the double effect condensers *N* with their condensing fluid.

The small steam-engine close to the condensers is for the purpose of working the air and water pumps required in the several processes.

The tank *X* contains water for cleansing the clarifiers and the mechanical and charcoal filters, to which it is conducted by the pipe *g*.

After being partially concentrated by dropping over the pipes of the condenser, the juice, having been collected in a copper trough, is run into the cistern *O*, and is then raised up by the pressure of the atmosphere into the vacuum pan *P*.

The juice must not be too much concentrated over the condenser, or it would become thick and hang about the pipes, thus running the risk of becoming acid. The preliminary concentration is therefore continued in the vacuum pan *P*, to a density of about 27° Beaumé. The juice is then let down into the receiver *Q*, and is afterwards forced up by the monte-jus *R* into the cistern *S*. In this cistern is a single turn of steam-pipe, for the purpose of slightly raising the temperature of the juice, to enable it to run the quicker through the charcoal, through which it is passed a second time after traversing the pipe *h*. If this elevation of temperature were not effected, the juice, being now concen-

trated, and therefore thicker than when it was before filtered, would pass with difficulty through the charcoal.

Both the pipes, *f* and *h* (for the supply of the filters with juice at the two stages of the operation), are furnished with a ball-cock at each filter, to obviate by its self-action the risk of overfilling them. The juice after its second filtration is collected in one of the gutters at the foot of the charcoal filters, and run into the cistern *T*, from whence it is raised into the second vacuum pan *P'*, where the evaporation is completed.

There are three copper gutters connected with the outlets from the charcoal filters; one is for conducting away the weak juice after its first filtration, another for conveying away the partially concentrated juice after the second filtration, and the third for carrying away the water with which the filters have been washed.

The vapour generated in the vacuum pans passes along the pipes *U* and *U'* to the condensers. Each of these pipes has a valve *k* for shutting off the connection of either of the pans with the condensers.

The vapour having found its way to the condensers, is there condensed by imparting its latent heat to the weak cane-juice on the outside of the pipes, and is removed as water by a small air-pump attached to the steam-engine; the same pump also removes any air admitted into the vacuum pans.

The two vacuum pans in this apparatus are supported upon a light, handsome cast-iron stage, with railings round it, which, besides having a very pleasing effect, occupies less space than the ordinary clumsy wooden frame-work.

The evaporation being completed in the second vacuum pan, the sugar is let down into the two heaters *V* and *V'*, and afterwards is ladled out into the moulds in the fill-house.

As a much lower pressure of steam must be used in the vacuum pans than is employed in the other parts of the apparatus, an expansion vessel *W* is supplied for reducing this pressure.

The apparatus *Y* shown in the plan behind the boilers is the charcoal reburning apparatus, in which the charcoal, after being once used, is revivified, or has the organic matter it has accumulated destroyed.

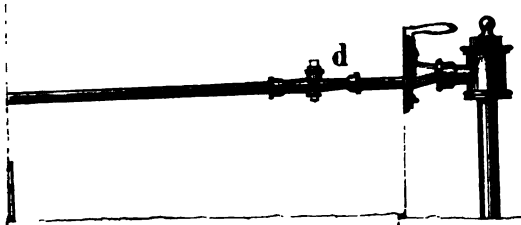
The pipes through which the steam is supplied to the different vessels from the boilers may be traced in the drawings, and do not therefore require detailed explanation.

This set of machinery differs from some others erected by the same manufacturers, in having two vacuum pans, one of which is used for completing the preliminary concentration. No doubt it is much better to have another pan for this purpose; but for the sake of saving the

cost of a second pan, the juice, after being partially evaporated over the condensers, is generally brought up to the density at which it should go into the finishing pan in open steam or fire evaporators. Generally speaking, also, so much space cannot be allotted to the apparatus as was available in the present case. The arrangement of the position of the apparatus must of course always depend upon the size and shape of the building in which it is to be erected.

This set of apparatus, together with another somewhat smaller, were constructed for two contiguous estates, belonging to the same person, in the Island of Cuba, and were estimated to make the one 11 and the other 9 tons of sugar per day of twenty hours. They are capable, however, of making considerably more if required.

Plate VIII. represents Mr. Bessemer's plans for curing sugar by centrifugal machinery, as described in the text.



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